Studies on the effect of Co-inhabitation of *Meloidogyne incognita* (Kofoid and White) Chitwood and *Macrophomina phaseolina* (Tassi) Goid on *Cicer arietinum* L.

THESIS SUBMITTED FOR THE DEGREE OF

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IN

BOTANY

BY

Zaki Anwar Siddiqui

DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

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CHECKED-2002

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TO MY

GRAND MOTHER

Dr. Syed Israr Husain
M.Sc., Ph.D. (Alig.) F L.S. (London)
PROFESSOR OF BOTANY
ELECTED MEMBER:
ACADEMIC COUNCIL & C.A.S.R.
DEPARTMENT OF BOTANY,
ALIGARH MUSLIM UNIVERSITY,
ALIGARH (INDIA)

Dial Off : 5676
Res : 7325
'MAAMAN'
4/812, Sir Syed Nagar,
Civil Lines, Aligarh-202002
INDIA

Dated.....

Ref. No.....

CERTIFICATE

This is to certify that the thesis entitled "Studites on the effect of co-inhabitation of Meloidogyne incognita (Kofoid & White) Chitwood and Macrophomina phaseolina on Cicer arietinum L." is a faithful record of the bonafide research work carried out by Mr. Zaki Anwar Siddiqui under my guidance and supervision. His work is upto-date and original. He is allowed to submit his thesis to Aligarh Muslim University, Aligarh for the consideration of the award of the degree of Doctor of Philosophy in Botany.

(S. Israr Husain)

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Z Siddiqui

(Zaki Anwar Siddiqui)

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INTRODUCTION

Pulse crops occupy very important position in Indian agriculture as they contain nearly three times as much proteins as in the cereals. Moreover, proteins from pulses are generally cheaper. They are, therefore, the main source of protein (Jeswani & Vanchaik, 1968; Chand & Shrivastava, 1982) for the predominantly large vegetarian population of the country. Besides being the important constituent of human diet pulses also serve as suitable green manure crops and as excellent forage and grain concentrates for cattle feed (Kaul & Sekhon, 1974). These crops are generally included in cropping system patterns in most of the areas as they help to keep the soil alive and productive because of their unique ability to fix atmospheric nitrogen with the help of nitrogen fixing bacteria. It is estimated that 14.53 meteric tons of nitrogen is fixed annually by the symbiotic association of nitrogen fixing bacteria and the legumes (Quispel, 1974). Pulse crops are useful in drawing out plant nutrients from deeper soil layers with the help of deep root system and making them available in the form of plant residues.

Pulses, in India, occupy an area of about 23 million hectares but the production has been stagnating between 10-12 million tons only. Per capita availability of pulses

has declined from 70.4 to 38.5 g during the last 26 years. They are predominantly grown under rainfed and marginal land with low input levels and plant protection cover. Problem of increasing pulse production has become more challenging in view of 35 million tons target to be achieved by the end of 2000 A.D.

Chickpea (Cicer arietinum L.) is most important pulse crop of India and the best legume for human consumption. It occupies about 3/4 of wheat acreage of India and constitutes nearly 2/5 of the pulse crops of the country. Northern India accounts nearly 90% of the annual area and about 95% of the production.

Chickpea is always grown as cold weather (Rabi) crop. It is grown alone or mixed with wheat, barley, linseed, safflower or mustard. Gram does not need a very fine seed bed. Sowing is done in October and November. The crop is irrigated once or twice and only when soil gets much dried. The crop matures within 95 to 150 days after sowing depending upon the variety sown. Harvesting is usually done from middle of March to April. Gram prefers clay to light loamy soil.

Dal, besan, flour crushed or whole gram boiled or parched, roasted or cooked, salted or unsalted or sweet preparations and green foliage and grain as vegetables are the important forms in which it is consumed by the people.

Germinated seeds are recommended against scurvy. Malic and Oxalic acids collected from green leaves are prescribed for intestinal disorders. Soaked grain and husk are fed to horses and cattle as concentrate and roughage respectively. Thus chickpea is a prized crop which needs suitable protection from diseases.

The common fungal diseases of chickpea that occur in India are blight (Mycosphaerella rabiei), dry root-rot (Macrophomina phaseolina), root-rot (Fusarium solani, Operculella padwickii, Pellicularia filamentosa), stem-rot (Sclerotinia sclerotiorum), wilt (Fusarium oxysporum f. ciceri) and rust (Uromyces ciceris-arietini). The nematodes found associated with chickpea and those known to parasitize it include Meloidogyne javanica, M. incognita, Rotylenchulus reniformis, Heterodera cajani, H. vigni, Tylenchorhynchus brevidens, T. brevilineatus, T. mashhoodi, T. vulgaris, Hirschmaniella mucronata, H. oryzae, Helicotylenchus dihystera, H. sharafati, Tylenchus spp. and Xiphinema basiri. Though 11 genera and 26 species of nematodes are known to parasitize chickpea (Gill, 1989) but only four nematode species namely Heterodera cajani, Meloidogyne javanica, M. incognita and Rotylenchulus reniformis are considered of significant importance in India.

Soil is a complex ecosystem that supports a wide variety of life forms including plants and animals. The

plants, being primary producers form the direct or indirect source of food for consumers of all trophic levels including plant pathogenic organisms. It is well known that certain fungi, bacteria and viruses are important pathogens and often cause damage without being influenced by other biotic agents. However, plants are rarely, if indeed ever, subjected to association with only one potential pathogen. Plants are constantly, exposed to numerous pathogenic organisms many of which are common components of soil biosphere. Nematodes are of tremendous importance as component of disease complex along with other disease causing agents. We are usually unaware of their presence because of their microscopic size and protected position within the soil. When a plant is infected with one pathogen its response to another pathogen is likely to be altered. These alterations exert significant influences upon disease development within a particular host, etiology of all pathogens involved and ultimately on disease control. Keeping this in view, the study of disease complexes is as important as the study of monopathogenic situations because, under field condition, there is probably no soil borne disease that can be said to be of monopathogenic origin. Moreover, certain micro-organisms are destructive only when they occur in combinations with other biological agents. Nematodes contribute to disease complexes mostly by

modifying the physiology of host and occasionally by causing mechanical injury to the host. A good number of publications dealing with interactions between nematodes and fungi have appeared during the last 3 decades (Powell, 1968, 1971; Sidhu & Webster, 1977; Prasad et al., 1980; Kellam & Schenk, 1980; Khan et al., 1980; Morell & Bloom, 1981; Husain et al., 1985) showing the frequent and widespread involvement of nematodes and fungi in plant disease complexes. It is not, therefore, surprising that many more such complexes may come to light in future studies.

During the course of survey of Aligarh and Farrukhabad districts of Uttar Pradesh for plant parasitic nematodes and fungi (both from rhizosphere and rhizoplane). I observed frequent and simultaneous occurrence of Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949 and Macrophomina phaseolina (Tassi) Goid in the root and soil samples collected from chickpea fields. I, therefore, thought it desirable to study the effect of co-inhabitation of M. incognita and M. phaseolina on chickpea cv. P-256 as no work has so far been done on this problem of chickpea to the best of my knowledge. Experiments were conducted to study the :

1. effect of different inoculum levels of M. incognita and M. phaseolina on chickpea growth, its protein content and peroxidase activity with a view to determine the

inoculum threshold level of each pathogen;

2. effect of interaction of variable inoculums of above test pathogens on plant growth parameters and nematode multiplication;

3. effect of simultaneous, pre and post inoculation of test pathogens and rhizobium on plant growth parameters and nematode multiplication;

4. growth responses of 65 chickpea vars. against M. incognita and M. phaseolina and determination of protein content and peroxidase activity for resistance/susceptibility correlation;

5. management of M. incognita and M. phaseolina on chickpea by ascorbic acid and Paecilomyces lilacinus;

6. management of test pathogens through plant extracts and four biocontrol agents (two bacteria and two fungi); and

7. management of test pathogens by the application of culture filtrates of certain soil fungi.

REVIEW OF LITERATURE

Pathogenicity

Pathogenicity tests of several species of plant parasitic nematodes on pulse crops have been conducted by a number of workers (Sharma & Sethi, 1975; Raut, 1980; Srivastava *et al.*, 1979; Chahal & Singh, 1984; Khan, 1986 etc.) but conclusive evidence is not available to demonstrate the population threshold and pathogenicity of any particular nematode on many crops and their cultivars. Pathogenicity tests are necessary to determine the economic threshold level of a particular pathogen under a particular set of conditions for different crop cultivars because it has significant bearing on the disease development. Little information is available for such studies on *Cicer arietinum* L.

Srivastava *et al.* (1974) studied the effect of different inoculum levels of *Meloidogyne javanica* on chickpea. They reported continuous reduction in length and weight of shoot and root with the increase in inoculum level. Significant reduction was found only when 100 or more nematode larvae per 500 gm of soil were inoculated. Maximum reduction was observed at 10,000 level. Gaur *et al.* (1979) studied the effect of date of sowing in relation to population density of *M. incognita* and growth of three varieties of chickpea. They reported that reduction in

shoot growth was maximum at ideal sowing time i.e. October, followed by in September. When sowing was done in November and December the extent of damage was minimum probably because of low temperature which did not favour infection, development and reproduction. At nematization level below the injury threshold i.e. 1000 second stage juveniles per 1000 cc of soil, the plant growth was best in October sowing, but at higher level growth was best in November sowing. The variety L-550 developed more shoot growth than BG-203 and H-208. Nath et al. (1979) reported that increase in the level of larval inoculum of M. incognita resulted in proportional decrease in plant growth, flowering, fruiting and bacterial nodulation in chickpea. The inoculum of 100 larvae per 500 gm soil was found as damaging threshold. Dhangar and Gupta (1983) reported that an initial inoculum of 10,000 larvae of M. javanica per plant in smaller pots (15 cm) after two months of inoculation and 1,000 & 10,000 larvae per plant in large pots (25 cm) after five months of inoculation were pathogenic to Cicer arietinum in all three types of soil (Sandy, loamy sand and sandy loam). Seeds treated with Rhizobium showed better growth characters than untreated ones but there was no difference in pathogenic level in both treatments when infected with M. javanica. Mani & Sethi (1984a) studied pathogenicity of M. incognita on chickpea cultivar Pusa-209 using five inoculum levels

(0.5, 1, 2, 4 and 8 larvae per gm soil). They reported progressive decrease in plant growth with the increase of inoculum level. Inoculum of 2 larvae per gm was found to be the damaging threshold and rhizobial nodulation was adversely affected by all inoculum levels. Ahmad & Husain (1988) observed significant reduction in quantitative characters of Cicer arietinum plants when inoculated with 1,000 juveniles of M. javanica. They reported that an increase in the initial inoculum level led to the corresponding decrease in the growth parameters. Maximum reduction in all growth parameters was noticed at highest inoculum level (10,000 juveniles per pot). Tiyagi & Alam (1988) noticed that plant growth of two chickpea cultivars (Pusa-209 and K-850) was adversely affected by Rotylenchulus reniformis. All the inoculum levels (10, 100, 1000, 5000 and 10,000 per kg soil) caused damage but significant reduction in plant weight was observed at 1000 or more nematodes per plant. A direct correlation was found between the inoculum level and plant weight reduction. Pusa-209 was more favourable host for nematode than K-850. The rate of multiplication was higher at lower inoculums.

Interactions

Atkinson (1892) was the first to report nematode fungal interaction on cotton. He reported that infection of root-knot nematodes (Meloidogyne spp.) increased the

severity of Fusarium wilt on cotton. Although considerably large number of studies have been carried out on interactions involving different nematodes, fungi, bacteria and viruses but it appears impossible to estimate the number of such complexes that are likely to occur under natural conditions. In the following paragraphs I have attempted to present a review on the nematode fungus and nematode root nodule bacterium interactions.

Nematode-fungus interactions

Depending upon the parasitism of the fungus involved, these interactions for convenience sake, can be grouped into the following three major types.

(i) Nematode fungus wilt disease interactions

(ii) Nematode fungus root-rot interactions

(iii) Nematode fungus seedling disease interactions

I have further categorized each of the above types of interactions on the basis of nematode parasitism (i.e. with endo, semi endo or ectoparasitic nematodes).

(i) Nematode fungus wilt disease interactions

(A) Sedentary endoparasitic nematodes

(a) Root-knot nematodes

Harrison and Young (1941) reported that the loss from tomato wilt caused by Fusarium sp. was reduced where root-knot resistant peanut plants were grown in crop

rotation. Filipjev & Schuurmans-Stekhoven (1941) studied the interaction between root-knot nematode and Fusarium oxysporum var. vasinfectum on cotton. They observed higher percentage of wilting in Fusarium susceptible cotton plants when inoculation of nematodes preceded fungus by 2 weeks or fungus was used alone. Mc Clellam & Christie (1949) reported that severity of Fusarium wilt on cotton was reduced when soil fumigants were used to control the root-knot nematodes. Martin et al. (1956) studied the development of Fusarium wilt on cotton and reported that M. incognita and M. incognita acrita significantly increased the cotton wilt caused by Fusarium oxysporum var vasinfectum although Meloidogyne isolates differed in their ability to increase wilt incidence. Rankin (1957) observed increase in the mortality of okra plants when M. incognita and F. oxysporum var. vasinfectum were present together. Jenkins & Coursen (1957) induced wilting in Fusarium wilt resistant tomato (var. Chesapeake) by inoculating with M. incognita acrita and M. hapla. Thomson et al. (1959) observed that 2 varieties of cowpea Vigna sinensis (Grant and Chino 3) developed severe wilting in soil infested with M. javanica and F. oxysporum f. trachiefilum than in soil infested with F. oxysporum f. trachiefilum alone. They reported that in the field preplanting soil fumigation reduced the Fusarium wilt disease by 71% for grant and 41% for Chino 3. It also increased yield about 3-fold.

Schindler et al. (1961) investigated the interaction of root-knot nematodes with F. oxysporum f. dianthi on carnation plants. They reported that incidence of Fusarium wilt was significantly higher in the presence of any Meloidogyne spp. such as M. arenaria, M. arenaria thamesi, M. incognita acrita and M. javanica. Giamalva et al. (1962) studied the effect of root-knot nematodes on Fusarium wilt of sweet potato varieties Heartgold and Goldrush, resistant to root-knot and F. oxysporum f. batatas respectively. They noted no significant effect of any root-knot nematode species on wilt development in either sweet potato variety and concluded that the injury caused by root-knot nematodes was of no significance to sweet potato wilt. Minton & Minton (1963) studied histopathology of the infected sites of cotton plants parasitized by M. incognita acrita and F. oxysporum f. vasinfectum. They reported that fungus was found in the phloem or cambium but abundant growth occurred in xylem and nematode induced giant cells. The fungus was also found in sloughing epidermal cells and decaying cortex but poorly developed in healthy cortical tissues. Davis and Jenkins (1963) studied the effect of soil type and Meloidogyne spp. on etiology of pea wilt incited by F. oxysporum f. pisi race-1. Inoculation with M. incognita acrita and M. hapla resulted in the early appearance of wilt symptoms in wilt susceptible var. Pluperfect and broke resistance of pea variety Alaska to

the wilt pathogen. Goode and Mc Guire (1967) observed that infection of root-knot nematodes enabled certain races of F. oxysporum f. lycopersici to infect tomato variety ordinarily resistant to them. They suggested that fungus mutates within the host and has a chance to become established. Johnson and Littrell (1969) investigated the effect of different species of root-knot nematode (M. incognita, M. hapla and M. javanica) on severity of Fusarium wilt of Chrysanthemum. They reported that presence of nematode did not break the wilt resistance of variety 'Iceberg', however wilt symptoms appeared earlier and were more severe among 'Yellow Delaware' (Fusarium-susceptible) plants inoculated with M. javanica and F. oxysporum than with similar combination of fungus and M. incognita or M. hapla or with fungus alone. Powell and Batten (1969) reported that M. incognita predisposed tobacco plants to F. oxysporum f. nicotianae and plants infected with these two pathogens were predisposed to a foliar pathogen, Alternaria tenuis. Goswami et al. (1970) studied the effect of interaction of M. incognita and Sclerotium rolfsii on brinjal. They noted that inoculation with only nematodes caused no wilting while inoculation with fungus alone resulted in 6.25% wilting of plants. On the other hand, inoculation with both the pathogens resulted in complete wilting of 25% plants. Overman & Jones (1970) found that M. incognita and Verticillium alboatrum caused highest incidence of wilt on

tomato at 20°C. Sumner & Johnson (1973) reported that expression of disease symptoms and severity of Fusarium wilt of Watermelon were significantly correlated with the initial population of Meloidogyne larvae in the soil. Severity of disease was not correlated with the pH of soil. Pitcher (1974) observed reduction in resistance of tomato (Pearson VF_1) to F. oxysporum f. lycopersici by M. javanica. He noted greater disease interaction in 4 week old plants than in 8 week old plants with increasing time interval (upto 35 days) between inoculation of M. javanica and subsequent inoculation of Fusarium. Nematode infected roots harboured more fungus growth and pointed out that changes in the host physiology due to nematode infection influenced its subsequent response to fungal invasion. Sidhu & Webster (1977) concluded that M. incognita predisposed tomato plants to the infection of F. oxysporum f. lycopersici. Jacobsen et al. (1979) observed that M. hapla increased the severity of Verticillium wilt in potato. They noted that nematode populations were higher in root system of plants infected with fungus than in plants infected with nematode alone. Nath and Dwivedi (1980) observed early and greater manifestation of wilt and root-rot symptoms on chickpea when inoculated with Meloidogyne sp. and F. oxysporum f. ciceri or Meloidogyne sp. and Rhizoctonia sp. respectively. Price et al. (1980) reported that Verticillium dahliae and F. oxysporum f. lycopersici together did not influence galling

on tomato caused by Meloidogyne sp. but F. oxysporum, when present with root-knot nematodes, significantly reduced root galling. Padil et al. (1980) reported that concomitant inoculation of root-knot nematodes (M. incognita, M. hapla) and F. oxysporum f. pisi at planting resulted in death of pea plants. Prasad et al. (1980) studied the role of Corticium rolfsii and M. incognita in the wilt complex of Solanum khasianum. The two pathogens together caused more wilting than caused by fungus alone while the nematode caused no wilting. Melakeberhan & Evans (1981) studied the interaction of M. incognita and vascular wilt fungi (Verticillium alboatrum and F. oxysporum f. vasinfectum) on two cotton varieties (UK-71, UK-77). Verticillium alboatrum had no visible effect on the plants inoculated either separately, simultaneously or sequentially. Both cotton varieties wilted more and weighed significantly less when treated with the nematode and F. oxysporum simultaneously or 2 week apart than did the untreated control. They concluded that M. incognita played an important role in breaking Fusarium wilt resistance in cotton. Kleineke-Borchers and Wyss (1981) studied physiological changes in Fusarium susceptible and resistant tomato after infection by M. incognita. They noted that there was no enrichment of carbohydrates especially of reducing sugars, glucose and fructose as well as of free amino acids in roots of resistant plants while these components had a positive

effect on the fungus growth *in vitro* and *vivo*. They, therefore, concluded that enrichment of carbohydrates might have been responsible for inducing susceptibility. Morell & Bloom (1981) studied effect of temperature on the predisposition of tomato to Fusarium wilt by *M. incognita* and reported that highest incidence of wilt was found at 21-24°C. Singh *et al.* (1981) observed synergistic interaction of *M. incognita* and wilt fungus, *Fusarium*, on french beans and reported that simultaneous inoculation of both pathogens and prior inoculation of *M. incognita* resulted in maximum wilting of plants. Ibrahim *et al.* (1982) investigated the effect of *M. incognita* race-3 and *F. oxysporum* f. *vasinfectum* on wilt expression, nematode infestation, plant growth and mineral content of cotton (*G. barbadense* L.) cultivar Giga 69. They reported that presence of nematode enhanced the severity of wilt and the disease was observed 10 days earlier in case of concomitant infection. Level of wilt incidence, nematode infestation and reduction in plant growth were almost more than 2-fold when the two pathogens were present together. Combined infection of both pathogens significantly reduced Fe, K, Mg, Zn and Cu contents but increased N and Ca content quite significantly. Negron *et al.* (1982) studied the interaction of *M. incognita* and *F. oxysporum* f. *coffeae* on coffee. They noted chlorosis, root necrosis, wilting and dwarfing significantly greater in plants inoculated with

fungus four weeks after nematode inoculation than in plants inoculated two weeks later or with either of the pathogen alone. Plecz et al. (1983) noted that wilt pathogen of tomato, F. oxysporum f. lycopersici, was not pathogenic to cucumber in the absence of root-knot nematode (M. incognita) but in the presence of nematode wilt symptoms were developed. However, no effect of F. oxysporum f. cucumerinum was found on tomato. Goel and Gupta (1984) studied the interaction of M. javanica and F. oxysporum f. ciceri on chickpea and reported that shoot length was greatly reduced when fungus was inoculated a week after nematode inoculation. Root length, fresh shoot and root weight were also significantly less when fungus inoculation was made before nematode inoculation. They also investigated interaction between M. javanica and F. solani and noted that shoot and root length, fresh shoot and root weight were significantly less in treatments when F. solani was introduced a week after nematode inoculation as compared with other treatments. Hillocks (1986) observed localised and systemic effect of root-knot nematode, M. incognita on incidence and severity of Fusarium wilt in cotton. He reported that wilt incidence was increased by nematode, but only in plants where both organisms were present together on the same part of the root system. However, in a second experiment in which plants growing in Meloidogyne infested soil were stem inoculated with wilt pathogen, the nematode

caused an increase in wilt severity despite the physical separation of two organisms. Patel et al. (1987) investigated the interaction of M. incognita and F. oxysporum f. ciceri on chickpea variety Chaffa. They first observed wilting on 60th day of sowing in different treatments and reported that simultaneous inoculations with nematode and fungus resulted in more wilt (37.5%) than inoculations with 10 days interval (12.5%). Presence of nematode with fungus (prior, later or simultaneous) increased the incidence of wilt after 70 days of sowing. Upadhyay & Dwivedi (1987a) studied the interaction of M. javanica and F. oxysporum f. ciceri on chickpea. They observed that plant growth was adversely affected with both organisms, individually as well as in combination, with significant reduction in all growth parameters except plant height and root weight. Maximum reduction in shoot weight was observed where nematode preceded fungal inoculation by 10 days. Wilt symptoms, epinasty, drying and yellowing of leaves were much more in plants simultaneously inoculated with both the organisms than in the other treatments. This was followed by nematode preceding fungus and fungus alone inoculations. The effect of two organisms was additive. The same authors in the same year in another publication reported that root-knot nematode, M. javanica was able to break the wilt resistance of chickpea variety Avrodhi. Mani & Sethi (1987) observed the effect of combined inocula of

M. incognita, F. oxysporum f. ciceri and F. solani on the growth of chickpea variety JG-62 and it was additive in nature. They reported that resultant effect was more than additive when nematode was established earlier than the two fungi. All the three organisms affected the rhizobial nodulation considerably. Occurrence of M. incognita in combination with F. oxysporum f. ciceri and F. solani not only increased the severity of disease but also shortened the incubation period for disease expression. When the nematode preceded fungi the plant drying due to infection by F. solani appeared early. The nematode development and multiplication was adversely affected by F. solani irrespective of the time and level of inoculum while F. oxysporum f. ciceri did not affect the nematode population significantly.

(b) Cyst forming nematodes

Ross (1965) reported that prior inoculation of H. glycines predisposed soybean plants which resulted in increased Fusarium wilt. Jorgenson (1970) studied interaction between H. schachtii and F. oxysporum on sugarbeet and reported that damage to sugarbeet was less when both nematode and fungus were present because fungus inhibited nematode invasion and development. Miller (1975) observed that Fusarium wilt of tomato was reduced while Verticillium wilt increased in the presence of

Globodera tabacum. Harig (1976) pointed out that F. oxysporum f. lycopersici infecting tomato competed for its nutrient with Globodera rostochiensis and invaded giant cells resulting in the development of less number of mature females and small sized cysts. Gill & Swarup (1977) reported that F. moniliforme and Helminthosporium gramineum singly or in combination with Heterodera avenae in different inoculum levels showed negative correlation in barley plants. Edward & Singh (1979) reported that Heterodera cajani caused less damage to pigeonpea plants when present along with Fusarium udum. La Mondia & Taylor (1987) observed that high inoculum densities of F. oxysporum alone readily killed broad-leaf tobacco plants regardless of Globodera tabacum infection but at lower F. oxysporum densities, G. tabacum densities above 25 juveniles per cubic centimeter of soil increased wilt in tobacco, both susceptible and resistant to Fusarium.

(B) Interaction with migratory endoparasitic nematodes

Mountain & Mc Keen (1962) studied relationship between Pratylenchus penetrans and Verticillium dahliae on brinjal and tomato. They reported that in the presence of fungus reproduction of nematode was higher in brinjal roots than in tomato roots. Bergeson (1963) reported that in the presence of P. penetrans and V. alboatrum together on peppermint (Mentha piperata), wilt symptoms appeared two weeks earlier

than when fungus was present alone. Faulkner & Skotland (1965), on the other hand, noted that concomitance of P. minyus and V. dahliae increased severity of wilt and reduced incubation period for Verticillium wilt on peppermint. The rate of reproduction of P. minyus was greater in plants infected with both the pathogens. Edmunds & Mai (1966a) observed that P. penetrans, randomly distributed in 1% agar, moved towards a point source of carbon dioxide (100%). They reported that P. penetrans moved towards alfalfa roots infected with F. oxysporum when grown in agar medium. Roots infected with F. oxysporum exuded more Co_2 in comparison to uninfected roots. Morsink & Rich (1968) observed that Verticillium wilt of potato caused by V. alboatrum increased in the presence of P. penetrans. Faulkner & Bolander (1969) studied the effect of soil temperature on initial symptom expression of Verticillium wilt on peppermint in the presence of P. minyus. They reported that optimum soil temperature for development of wilt in the presence of nematode was 27°C while for fungus alone it was 24°C. Olthof & Reyes (1969) investigated the effect of P. penetrans and V. dahliae on pepper (Capsicum annuum) variety Vindale and concluded that damage caused by these two pathogens concomitantly was additive. Height of the plants and weight of shoots and roots were significantly reduced. Seinhorst & Kuniyasu (1971) studied the interaction of P. penetrans and F. oxysporum f. pisi race-2 on pea and

reported increased wilting of pea var. Rando in the presence of nematode. Conroy et al. (1972) reported that infection incidence of V. alboatrum increased on tomato variety Bonnybest with the increase in the P. penetrans population. Michell & Powell (1972) observed the influence of P. brachyurus on the incidence of Fusarium wilt on cotton. They reported greater wilting when nematode and fungus were inoculated simultaneously than when the nematodes were added 2 weeks prior to the fungus or when fungus was used alone. Udagava & Iyatomi (1972) concluded that the presence of P. penetrans accelerated colonization of cucumber roots by F. oxysorum f. cucumerinum. Burpee & Bloom (1974) suggested that infection of potato cultivar 'Katahdin' roots by P. penetrans and V. alboatrum resulted in a decrease in incubation period for the fungus. Occurrence of chlorosis in the nematode infected and control treatments was noticed three weeks after infestation. Infection by P. penetrans did not affect the onset of senescence in 'Katahdin' potatoes. Saadabi et al. (1986) observed that although the three Gossypium barbadense cultivars differed in their susceptibility to Pratylenchus sudanensis, they invariably showed greater and faster infection, and the number of wilted plants were greater when F. oxysporum f. vasinfectum infection occurred in the presence of nematode.

(C) Interaction with semi-endoparasitic nematodes

Neal (1954) studied the role of reniform nematode in the incidence of Fusarium wilt on cotton and reported that

presence of R. reniformis increased severity of the wilt. Tchatchoua & Sikora (1978) reported inhibition in growth of cotton due to interaction of R. reniformis and Verticillium dahliae. They observed that these two pathogens increased the intensity of wilt in unsterilized soil indicating the role of rhizosphere micro-organisms in increased level of damage caused by assistance of these two pathogens. Prasad & Padaganur (1980) investigated the interaction of R. reniformis and V. dahliae on four cotton varieties namely RRD-236, RRD-276, RRD-386-4 and CPD-8-I. They reported that all the four varieties harboured more nematode population in Verticillium infected plants as against the healthy plants. Tchatchoua & Sikora (1983) noted synergistic interaction between R. reniformis and V. dahliae on cotton. Inolculation of resistant cotton varieties with R. reniformis caused significant reduction in shoot and root dry weight at population densities of 5000 and 10,000.

(D) Interaction with ectoparasitic nematodes

Holdeman & Graham (1954) observed that sting nematode, Belonolaimus sp. was responsible for breaking resistance of cotton against wilt caused by Fusarium sp. They also noted that Tylenchorhynchus claytoni increased severity of wilt in tobacco in the presence of Fusarium sp. Martin et al. (1956) studied the interaction of F oxysporum f. vasinfectum with Trichodorus sp., Tylenchorhynchus sp. and

Helicotylenchus sp. on cotton and reported that little or no injuries were caused by these nematodes. Labruyere et al. (1959) reported that the appearance of symptoms of "early yellowing" disease or root-rot of pea was dependent upon the presence of both Hoplolaimus uniformis and F. oxysporum f. pisi race-3. Schindler et al. (1961), while studying the interaction between some ectoparasitic nematodes such as Helicotylenchus nannus, Rotylenchus buxophilus and F. oxysporum f. dianthi, noted that incidence of Fusarium wilt of carnations was not markedly affected by these nematodes. Cooper & Brodie (1963) noted that sting nematode, Belonolaimus gracilis was as efficient as root-knot nematode in promoting wilt in cotton. Davis & Jenkins (1963) reported that Tylenchorhynchus claytoni though not contributed to wilt development but increased more rapidly on pea roots infected with F. oxysporum f. pisi race-1 than on roots free from the fungus. Overman & Jones (1970) reported that Tylenchorhynchus capitatus in association with V. alboatrum caused highest incidence of wilt on tomato at 23°C. Seinhorst & Kuniyasu (1971) reported that rate of multiplication of Rotylenchus uniformis increased in the presence of F. oxysporum f. pisi race-1 on pea plants. Wehunt & Weaver (1972) studied the interaction between Hoplolaimus galeatus, Tylencholrhynchus claytoni, Criconemoides xenoplax and F. oxysporum. Peach plants inoculated with fungus and H. galeatus were markedly smaller

than plants of other treatments. Nath et al. (1974) reported that Hoplolaimus indicus and F. moniliforme together caused much greater reduction in growth of maize plants than caused by the nematode or fungus alone. Nematode population was greatly reduced in the presence of fungus on maize. Overman & Jones (1977) studied the interaction of Verticillium with Belonolaimus longicaudatus and Criconemoides sp. on tomato. They observed that wilt symptoms were much more pronounced at 28°C. It was in contrast to the earlier observations that Verticillium wilt is a cold weather disease. Nyczepair & Pusey (1986) reported that root necrosis was more extensive in the presence of Fusarium solani or F. oxysporum than with Criconemella xenoplax on peach. Neither synergistic nor additive effect on root necrosis or plant growth occurred between C. xenoplax and the fungal pathogens.

(ii) Nematode fungus root-rot interactions

(A) Sedentary endoparasitic nematodes

(a) Root-knot nematode

Sasser et al. (1953) studied the effect of root-knot nematode, Meloidogyne spp. on the expression of black-shank resistance in tobacco. They reported that tobacco seedlings wilted within a week when Meloidogyne and Phytophthora parasitica var. nicotianae were inoculated. Later, these plants had black-shank symptoms and within a month all were

dead. They suggested that Meloidogyne altered the expression of black-shank resistance of the tobacco varieties used. Sasser et al. (1955) studied the role of root-knot nematode, Meloidogyne spp. in the breaking of resistance of tobacco plant. They observed early and greater manifestation of black-shank symptoms on plants that were inoculated with Phytophthora parasitica var. nicotianae and Meloidogyne spp. Reynolds & Hanson (1957) studied the relationship between M. incognita acrita and Rhizoctonia solani with regard to the incidence of post emergence damping-off of cotton and reported that an increase of Rhizoctonia disease was associated with the increase in the root-knot nematodes. Corresponding decrease in plant size and survival was also noticed. Powell & Nusbaum (1960) reported that presence of root-knot nematode with Phytophthora parasitica var. nicotianae increased the incidence of black-shank on tobacco. Walter & Hideo-koike (1962) reported that M. incognita acrita reduced sugarcane growth significantly and Pythium graminicola caused positive interaction with root-knot nematodes on top growth but not on root growth of the plants. Kushner & Crittenden (1967) reported increased decay of alfalfa roots by either F. roseum or F. oxysporum f. batatas when M. incognita acrita was also present. Powell & Batten (1967) observed extensive tobacco necrosis when R. solani was inoculated 3-4 weeks after M. incognita inoculation but only a trace of necrosis

was observed when nematode and fungus were added simultaneously and no necrosis when fungus was used alone. Miller (1968) investigated the effect of M. javanica on black-shank disease caused by Phytophthora parasitica var. nicotianae on tobacco NC-95. This variety was resistant to M. javanica and black-shank fungus separately and reported that when plants were inoculated with M. javanica and black-shank fungus about 64% plants showed black-shank symptoms. Littrell & Johnson (1969) reported that M. incognita increased the severity of Pythium root-rot of Chrysanthemum but fungus infected plants adversely affected nematode reproduction. Melendez & Powelll (1969) observed that Trichoderma a weak pathogen induced root decay in tobacco in the presence of M. incognita. Golden & Van Gundy (1972) reported that M. incognita infected tomato roots became more susceptible to R. solani and Thielaviopsis basicola exihibiting premature decay with increase in the age. They suggested that permeability alteration induced in tomato by M. incognita parasitism resulted in an increased leakage of electrolytes and that organic compounds would be of major importance in disease complexes. Saeed et al. (1972) investigated association of M. incognita and F. solani causing root-rot of papaya. They noticed that the disease was more severe when both pathogens were present together. Hutton et al.

(1973) reported that when red-kidney bean plants were subjected to a low inoculum level of F. solani f. phaseoli, more plants were affected by dry root-rot among plants infected with mixture of Meloidogyne spp. (M. arenaria + M. javanica) than among nematode free plants. When subjected to high inoculum level of fungus, all plants whether nematode free or nematode infected, became infected by fungus. Nematode infection had no effect on severity of the fungus disease. Golden & Van Gundy (1975) studied the disease complex of okra and tomato and reported that root decay by R. solani occurred 4-5 weeks after M. incognita infection. Penetration studies using cellophane membrane indicated that the fungus was specially attracted to nematode galled tissues and sclerotia were selectively formed on nematode galls. During development of nematodes in okra, total carbon and nitrogen contents were higher than in control. Goswami et al. (1975) reported that presence of M. javanica 3 weeks prior to the inoculation of Rhizoctonia bataticola resulted in maximum wilting (33.33%) of tomato plants. Simultaneous inoculation of both pathogens caused 13.33% wilting while in treatments having fungus alone and fungus preceded nematode inoculation by 3 weeks only 6.66% plants were wilted. Chhabra et al. (1977) observed significant reduction in lengths and weights of shoot and root of okra plants when inoculated with M. incognita and R. solani either simultaneously or with either of the pathogens

inoculated 10 days after the other. Maximum reduction in plant growth was noticed when nematode and fungus were inoculated simultaneously. Azam et al. (1977) reported that Colletotrichum atramentarium, a slow growing fungus, greatly damaged egg plant roots and reduced growth of the plants if preceded by M. incognita inoculation. Presence of M. incognita aggravated the root-rot of egg plant either caused by R. solani or Pythium sp. Bookbinder & Bloom (1977) reported that interaction of M. incognita and Uromyces phaseoli reduced shoot and root fresh weights of beans to a larger extent than the infection by either pathogen alone. Gall formation was reduced only when U. phaseoli was added several days before inoculation with M. incognita. Sinha et al. (1977) found that M. incognita and Ozonium texanum together caused greater reduction in egg plant growth than caused by either pathogen alone. Chhabra et al. (1978) studied the influence of soil types on interaction of R. solani and M. incognita on okra and reported higher population of nematodes in sandy loam soil. Kirmani et al. (1978) observed that development of root-knot nematodes on egg plant was reduced in soil infested with different fungi (Aspergillus terreus, A. versicolar, Penicillium caryophilum) in the presence or absence of oil-cakes. Vaishnav & Sethi (1978) reported that M. incognita and Sclerospora graminicola interacted synergistically and reduced growth of bajra plant. The

number of galls and final population was unaffected by the presence of fungus. Reddy et al. (1979) reported that M. incognita and R. solani caused root-rot disease of french bean. Inoculation of nematode alone, simultaneously and nematode inoculation 10 days after fungus drastically reduced the plant height and fresh weight. Maximum root-rot was noted when nematode and fungus were inoculated simultaneously. Sharma & Gill (1979) reported that M. incognita and R. solani reduced potato plant growth significantly in single inoculation and their combined effect was almost equal to their individual effect except where fungus preceded nematode inoculation. Severity of nematode infection was reduced in combined inoculation. Sharma et al. (1980) observed synergistic interaction of M. incognita and Rhizoctonia bataticola on okra. They reported large accumulation of total proteins, phenols and proline in roots infected with M. incognita or with R. bataticola and M. incognita both. Khan et al. (1980) reported synergistic interaction of M. incognita and Phomopsis vexans on brinjal. Chahal & Chhabra (1984) studied interaction of M. incognita and R. solani on tomato and reported that synergistic effect of simultaneous inoculation was apparent from significant reduction of shoot weight, length and root weight in comparison to the reduction caused by either pathogen alone. Inoculation of M. incognita 3 weeks prior to R. solani significantly reduced shoot weight and length in comparison

to inoculation of R. solani 3 weeks prior to M. incognita. This was attributed to the predisposition of seedling roots by nematodes for subsequent damage caused by R. solani. Al-Hazmi (1985) investigated the effect of M. incognita and Macrophomina phaseolina on root-rot of two cultivars of french bean. Severity of M. phaseolina root-rot increased by 54.5, 94.6 and 9.6% when both pathogens were introduced simultaneously, the nematode preceding by 2 weeks and the fungus preceding by 2 weeks respectively. Nematode infection and reproduction was adversely affected when the fungus was introduced first. Cultivar 'Harvester' was more tolerant to both pathogens and less susceptible to nematode than 'Romanio Italian'.

Husain et al. (1985) studied the interaction between Verticillium tenuipes, Trichoderma viridae and M. incognita on tomato. All three pathogens singly or in association significantly reduced root, shoot length, fresh and dry weight of the plants. Meloidogyne incognita and V. tenuipes together caused more damage than caused by all three pathogens together or by T. viridae and M. incognita combination. Interaction of these two fungi caused lesser damage than caused by them singly. Plant growth reduction caused by V. tenuipes was highest followed by M. incognita and T. viridae. Inoculation of V. tenuipes 15 days prior to M. incognita or simultaneously resulted in poorest galling

and nematode multiplication while T. viridae had no marked effect on galling and nematode multiplication. Patel et al. (1985) reported that when 1 gm fungus (F. solani) was inoculated with 1000 or 2000 larvae of root-knot nematode, M. arenaria on ground-nut, the wilting period was reduced to 16 and 13 days respectively. A similar trend was observed with 2 gm and 4 gm fungus and its combination with 1000 and 2000 nematodes. Goel & Gupta (1986) studied the interaction of M. javanica and Rhizoctonia bataticola on chickpea and noted that generally combined infection of both organisms, irrespective of time of inoculations, reduced various growth parameters compared to when they were inoculated alone. Number of root galls were significantly reduced when nematode was present a week before fungus inoculation compared to all other treatments. When fungus was introduced 30 days after nematode inoculation, the plant growth as well as number of root galls were significantly less as compared to when inoculated after 10, 20, 40 or 50 days of nematode inoculation. Sakhuja & Sethi (1986) reported that multiplication of M. javanica and galling on ground-nut was adversely affected by Rhizoctonia bataticola and Fusarium solani. The reduction in multiplication was maximum where one or both the fungi were inoculated simultaenously with the nematode. Kanwar et al. (1987) reported that shoot length, shoot dry weight and root dry weight were decreased in all the three soil types (Sand,

sandy loam and loamy sand) when inoculated with M. javanica and R. solani but only root dry weight was significantly reduced. Plant growth of cowpea was better in loamy sand and reduction in number of nodule was non-significant in all the three soil types. Acharya et al. (1987) investigated pathogenic association of M. incognita with Sclerotium rolfsii and Xanthomonas betlicola on Betelvine and reported maximum reduction in plant growth when all the three pathogens were present. The nematode population in the soil decreased to maximum when root-knot nematode was inoculated 3 weeks after fungus and bacterium inoculation. Kanwar et al. (1988) reported reduction in the growth of cowpea when M. javanica was inoculated 3 weeks prior to R. solani. Loamy sand was better for plant growth than other soil types. Number of galls were maximum when nematode and fungus were inoculated together. Khan & Husain (1988a) reported that individually Rhizoctonia solani was more pathogenic to cowpea followed by M. incognita and R. reniformis. On the other hand, concomitance of nematode and fungus was more pathogenic than the association of both the nematodes. Inoculation of Rhizobium prior to pathogen/pathogens resulted in less plant growth reduction, poor nematode multiplication, low root-knot index and improved nodulation as compared with its inoculation 15 days later. However, no significant difference in plant growth of bacterized plant was observed when inoculated

simultaneously with either nematode and fungus or when nematode preceded fungus.

(b) Cyst forming nematodes

Dunn (1968) reported more reduction in tomato growth when inoculated with Globodera rostochiensis prior to R. solani and Colletotrichum atramentarium than when fungus inoculation preceded nematode or when the plants were inoculated with both pathogens simultaneously. Ketudat (1969) observed an increase in the number of males of G. rostochiensis when R. solani was present in soil. Dave (1975) studied the relationship of R. solani with Heterodera glycines on Clark 63 soybean. Damage caused by R. solani in the presence of H. glycines was no more than additive. Nematode population and development was suppressed more in the presence of fungus. Roy (1977) studied interrelationship between G. rostochiensis and R. solani and Colletotrichum coccodes (the causal fungus of brown root-rot) on tomato. Plants showed greater growth reduction when nematode inoculation preceded fungus in comparison to a situation when fungus preceded nematode inoculation. This complex appeared to be complicated by possible interrelationship between the two fungi. Gupta et al. (1975) studied the effect of certain soil borne fungi on the development of Heterodera vigni on cowpea. They observed that these fungi significantly reduced nematode infection in

the given order: Penicillium citrinum, Aspergillus niger, Curvularia lunata, Rhizoctonia bataticola, Rhizopus nigricans and Aspergillus terreus. Hasan (1984) reported that when Heterodera cajani was associated with Fusarium udum on Cajanus cajan there was significant increase in wilting and highest incidence of wilt was observed when inoculation of H. cajani was done 3 weeks prior to fungus. Walia & Gupta (1986) observed that Rhizoctonia solani adversely affected H. cajani population when inoculated one week prior to nematode on cowpea. Number of cysts and larvae were significantly reduced over nematode alone. The fungus, when inoculated 2 weeks after nematode, reduced the top growth of plants significantly as compared to check or any other treatment. Evans (1987) noted that early maturing potato cultivars were less tolerant to potato cyst nematode than late maturing ones. Cultivars having H_1 resistant gene were more tolerant to Globodera rostochiensis than to G. pallida. When inoculation of Verticillium dahliae was made with potato cyst nematode, the wilt symptoms appeared much earlier on the early than main crop cultivars. There were differences in degree of susceptibility in different cultivars to the combination of nematode and fungus probably due to nematode causing different degree of trauma in the roots of different cultivars.

(B) Interaction with migratory endoparasitic rematodes

Benedict & Mountain (1956) observed association of Pratylenchus minyus and R. solani on wheat and reported that these two pathogens significantly reduced plant growth. This root-rot was characterized by yellow and stunted patches in wheat field. Edmunds & Mai (1966b) investigated the relationship of P. penetrans and Trichoderma viridae in alfalfa and celery. They reported that these two pathogens together caused more reduction in alfalfa and celery growth although Trichoderma spp. are known as weak pathogens. Palmer et al. (1967) reported that P. scribneri in association with F. moniliforme caused greater reduction in corn fresh weight than caused by either of them alone. Olthof (1968) observed that a fungus, Thielaviopsis basicola exercised some effect on root penetration by nematodes because P. penetrans did not alter resistance of barley and tobacco. Inagaki & Powell (1969) reported that Pratylenchus brachyurus and Phytophthora parasitica var. nicotianae simultaneously or with the former one week before fungus inoculation resulted in more rapid development of black-shank symptoms and more severity of disease on tobacco than when fungus was used alone. Nematodes apparently acted as wounding agent, thereby promoting fungus invasion. Santo & Holtzmann (1970) investigated that Pratylenchus zeae and fungus Pythium graminicola caused reduction in growth of sugarcane plant. Oyekan & Mitchell (1972) reported that the

severity of root-rot of canning pea caused by Aphanomyces euteiches was increased in the presence of P. penetrans. Hutton et al. (1973) reported that bean plants (Red kidney) when subjected to low level of F. solani f. phaseoli, more plants were affected by the dry root-rot among plants infected by P. penetrans than among nematode free plants. When subjected to a high inoculum level of the fungus all plants, whether nematode free or nematode infected, became infected by the fungus. Booth & Stover (1974) observed that Cylindrocarpon mussae was commonly found associated with Radopholus similis lesions on bananas. They pointed out that wounds created by nematodes were used by fungus for its invasion. Palmer & Mc Donald (1974) observed that F. moniliforme alone decreased the root and shoot weights of maize seedlings to a greater extent than the fungus in association with either P. scribneri or P. penetrans. Dave (1975) studied the relationship of R. solani with P. scribneri on Clark 63 soybean. He noted that damage caused by R. solani in the presence of nematode was no more than additive. Dee-Rodriguez & Ayala (1977) reported that combination of P. zeae with Curvularia sp. suppressed top and root growth of Sorghum bicolar and caused root necrosis. Sosamma & Koshy (1978) reported the association of Cylindrocarpon effusum and C. lucidum with Radopholus similis on coconut. They noted that fungus could be isolated only from cortical region and not from stelar region. Edward et al. (1984) reported that population of

Aphelenchoides besseyi increased 4-5 fold on the rice cultivars Saturn and Melrose and 3 fold on Nava-76 plants inoculated with A. besseyi and Sclerotium oryzae. Jordaan et al. (1987) reported that root lesion nematodes (P. brachyurus and P. zeae) and F. moniliforme affected plant growth more when combined than alone and most severely during the seedling stage. The presence of fungus facilitated the attraction and/or penetration of root-lesion nematode into the roots of maize seedlings.

(C) Interaction with semi-endoparasitic nematodes

O'Bannon et al. (1967) reported that citrus nematode, Tylenchulus semipenentrans, increased root decay caused by Fusarium spp. in lemon but there were differences in decay depending upon the species (F. oxysporum or F. solani). Kumar & Sivakumar (1981) investigated a disease complex involving R. reniformis and Rhizoctonia solani on okra. They noted that the presence of these two pathogens together resulted in wilting in early stage. When nematode inoculation preceded fungus, wilting occurred earlier than when in the absence of nematodes, depending upon the level of inoculum and the age of the plant. Low initial inoculum preceding fungus inoculum also caused early wilting irrespective of the density of the latter.

(D) Interaction with ectoparasitic nematodes

Haglund & King (1961) observed that the severity of root-rot of pea caused by Aphanomyces euteiches was

increased by the presence of Tylenchorhynchus martini but this increase in root-rot was significant only when strong pathogenic isolate of A. euteiches was used. Increase in the root-rot was directly related to the number of nematodes added. Kisiel et al. (1969) concluded that fungi are primary pathogens and nematode did not increase the invariable potential of the fungus nor the severity of the disease. In the study of interaction they reported that Tylenchus agricola and F. roseum resulted in increased penetration of vascular stele by the fungus. Fusarium roseum was more pathogenic than Pythium ultimum. Littrell & Johnson (1969) observed that disease symptoms appeared earlier and were more severe on 'Iceberg' Chrysanthemum when inoculated with Pythium aphanidermatum and Belonolaimus longicaudatus than on plants inoculated with fungus alone. Vargas & Laughlin (1972) studied interaction between F. roseum and Tylenchorhynchus dubius. They noted that development of symptoms were associated with Fusarium blight of Blue-grass. Tylenchorhynchus dubius appeared to be dominant pathogen in this relationship. Dave (1975) studied the relationship of R. solani and Tylenchorhynchus martini on soybean and reported that damage caused by R. solani in the presence of nematode was no more than additive. Effect of fungus on nematode population was least. Sobun et al. (1979) studied interrelationship between Tylenchorhynchus sp. and root-rot fungus on gram. They reported that

nematode adversely affected root-shoot ratio but this effect was more pronounced in the presence of nematodes.

(iii) Nematode fungus seedling disease interactions

(A) Sedentary endoparasitic nematodes

(a) Root-knot nematodes

Taylor & Wyllie (1959) studied the effect of root-knot nematodes and Rhizoctonia solani on soybean seedling emergence. They noted that the effect of M. javanica and M. hapla in combination with R. solani was much greater than caused by any one of them alone. Norton (1960) reported that root-knot nematodes in combination with R. solani increased severity of pre and post emergence damping off of cotton seedlings. Brodie & Cooper (1964) reported that cotton seedlings grown in soil infested with Meloidogyne spp. were more susceptible to R. solani than those grown in the absence of root-knot nematodes. Cauquil & Shepered (1970) reported synergistic effect on severity of cotton seedling disease between root-knot nematode, M. incognita acrita and Alternaria tenuis, F. oxysporum f. vasinfectum, Glomerella gossypii and R. solani. Cotton seedling diseases were severe in the presence of high inoculum levels of G. gossypii and R. solani without nematodes but at all these inoculum levels nematode effects were masked. Alternaria tenuis and F. oxysporum f. sp. vasinfectum alone caused slight or no disease but when combined with nematodes the

disease was severe. Tu & Cheng (1971) noted that incidence and severity of root-rot caused by Macrophomina phaseoli was increased in Kenaf seedlings simultaneously infected by M. javanica. In seedlings at 5, 10 and 15 days of age root lesions increased 70.3, 44.1 and 21.8% and nematode penetration increased 49.0, 36.7 and 12.3% when both fungus and nematode were present. Agrawal & Goswami (1973) reported that Macrophomina phaseoli and root-knot nematodes caused higher mortality of soybean seedlings particularly when they established earlier. Carter (1975a) reported that 2500 and 5000 M. incognita larvae/plant combined with R. solani increased seedling disease severity of cotton over that caused by R. solani alone. Optimum soil temperature for the disease development for combined infection was 18-21°C. Same author in another publication in the same year reported that synergistic effect of the interaction between R. solani and M. incognita on cotton seedlings increased with the increase in coarse particles in the test soil. Garcia & Mitchell (1975) reported that Pythium myriotylum, F. solani, R. solani and M. arenaria alone at inoculum densities of 2000 spores/gm of soil 1000 conidia/gm of soil, 10 sclerotia/gm of soil and 5 eggs/gm of soil respectively did not cause significant pre-emergence damping off of peanut seedlings. Pythium myriotylum interacted synergistically with F. solani and M. arenaria but not with R. solani in causing damping off. Carter (1981) reported

that root wounding mechanically or by M. incognita did not predispose the cotton seedlings to R. solani. Mani & Sethi (1984b) studied an interaction involving M. incognita, F. solani and F. oxysporum f. ciceri on chickpea. Fusarium solani was capable of hampering seedling emergence both individually or in combination with M. incognita and F. oxysporum f. ciceri. Maximum reduction in seedling emergence was observed when they were present together.

(b) Cyst forming nematodes

Polychronopoulos et al. (1969) noticed that Heterodera schachtii and R. solani, when present together, caused rapid softening and decay of sugarbeet tissues. Whitney (1974) reported synergistic interaction of Pythium ultimum and H. schachtii at all inoculum levels on the pre and post emergence damping off of sugarbeet. The effect of P. aphanidermatum and H. schachtii in combination was additive for damping off and root-rot of sugarbeet. Adeniji et al. (1975) reported that Heterodera glycines and Phytophthora megasperma caused more damage to soybean seedlings than any of them singly. Jayprakash & Rao (1984) studied rice seedling disease caused by Heterodera oryzicola and Sclerotium rolfsii. Higher percentage of seedling mortality was recorded in treatments with prior inoculation of nematodes followed by fungus than in treatments with fungus followed by nematodes. Penetration and development

of H. oryzicola was reduced in the presence of fungus.

(B) Interaction with migratory endoparasitic nematodes

Mauza & Webster (1982) observed synergistic disease interaction of alfalfa when F. oxysporum and Pratylenchus penetrans were added simultaneously to the soil. Alfalfa growth was suppressed at all inoculum levels of P. penetrans and F. oxysporum but not with F. solani. Fusarium oxysporum did not alter the population of P. penetrans whereas the presence of F. solani was associated with diminished number of P. penetrans in the roots.

(C) Interaction with semiendoparasitic nematodes

Van Gundy & Tsao (1963) found that the growth of citrus seedlings was significantly reduced by the concomitance of Tylenchulus semipenetrans and Fusarium solani. Either of the two pathogens had comparatively lesser adverse effect. Brodie & Cooper (1964) reported that cotton seedlings grown in soil infested with R. reniformis were more susceptible to R. solani than those grown in the absence of nematodes.

(D) Interaction with ectoparasitic nematodes

Brodie & Cooper (1964) studied the role of plant parasitic nematodes in pre and post emergence damping off of

cotton seedlings. They reported that cotton seedlings grown in soil infested with Hoplolaimus tylenchiformis were more susceptible to R. solani than in the absence of nematode. Khan et al. (1971) noticed that seedling emergence of cauliflower was much adversely affected by the concomitance of R. solani and Tylenchorhynchus brassicae. Rhizoctonia solani alone also reduced seedling emergence but T. brassicae alone had no effect on seedling emergence.

Nematode root-nodule bacterium association

Role of plant parasitic nematodes on nodulation and nitrogen fixation by the host plant has been investigated by a number of workers. As a result of nematode infection the nodulation is either suppressed (Masefield, 1958; Ross, 1969; Balasubramanian, 1971; Hussaini & Seshadri, 1975; Sharma & Sethi, 1976; Singh et al., 1977) or stimulated (Hussey & Barker, 1976) or remains largely unaffected (Taha & Raski, 1969).

(A) Effect of sedentary endoparasitic nematodes

(a) Root-knot nematodes

Miller (1951) was the first to observe inhibition of nodulation in peanut in the presence of root-knot nematode. Masefield (1958) reported that nematode galls affect nodulation by causing deficiency of nutrients in the host or by occupying major portion of root surface. Van Schreven (1958) reported deleterious effect of nematodes on

nodulation. Nigh (1966) observed that M. javanica suppressed nodulation on alfalfa. Simultaneous inoculation of nodule bacterium and the nematode resulted in greater reduction in nodulation but the nodules were rarely invaded by the nematodes while prior inoculation of bacterium facilitated the invasion of nodules by the nematodes. Balasubramanian (1970) reported that root-knot nematodes namely M. javanica, M. hapla and M. incognita caused reduction in bacterial nodulation in soybean. Greatest reduction was caused by M. javanica but there were no differences between inoculations with 100 and 1000 larvae. He suggested that reduction in nodulation might be due to direct interference of root-knot larvae with the establishment of nitrogen fixing bacteria or due to over all reduction of root system. Hussey & Barker (1974) observed that M. incognita and M. hapla stimulated nodule formation and growth of soybean and cowpea but had adverse effect on nitrogen fixation. Nodules of these crops were smaller and less efficient for nitrogen fixation. Baldwin et al. (1975) on the other hand, reported that M. incognita reduced nodulation on soybean plants. Hussaini & Seshadri (1975) observed that M. incognita besides being pathogenic to mungbean hampered nitrogen fixation. They concluded that reduction in nitrogen content was due to overall reduction in root nodulation and the anatomical changes in nodules and altered physiology of the host. Bopaiah et al. (1976a)

reported that inoculation of M. javanica prior to Rhizobium resulted in maximum reduction in nodules in mung. Infestation of nematode interfered with nitrogen fixation and reduced nitrogen content of shoot and root. Barker & Hussey (1976) studied the histopathology of nodular tissue of legumes infected with M. incognita (M. hapla on peanut). Meloidogyne incognita was generally found inside the vascular bundles in soybean nodules and did not alter structural integrity of soybean nodules but bacteroids did not develop adjacent to the nematodes and infected nodules deteriorated earlier than non-infected nodules. Nodule development was suppressed on wandopea and many deteriorates prematurely. Meloidogyne hapla were observed only few in nodules of peanut and little damage was caused when nematode invaded tissue adjacent to nodules.

Hussey & Barker (1976) reported that nodule formation was stimulated by M. hapla in soybean but nitrogen fixation capacity was inhibited. They observed that afluorescent plus incandescent light regimes resulted in plants with greatest shoot weight, pod number and nodule per gm of root. Singh et al. (1977) observed that with the increase in inoculum level of M. incognita there was corresponding decrease in chlorophyll content, number of nodules, nitrogen content of shoot and protein content of grain both in Rhizobium phaseoli inoculated and uninoculated treatments.

Baldwin et al. (1979) studied the effect of M. incognita on susceptible (Lee 68) and moderately resistant (Forrest) soybean. Nitrogen fixing capacity was evaluated after 50, 75, 100 and 135 days of inoculation. Nematode stimulated nitrogen fixation in Lee 68 by 50 days and in Forrest by 75 days. At all other intervals nitrogen fixation was either suppressed or unaffected by nematodes. Srivastava et al. (1979) reported that the growth of soybean, Glycine max, was affected when plants were inoculated with different inoculum levels of M. javanica. Number of nodules per plant were reduced significantly even at the lowest inoculum level (10 larvae/kg soil). There was correspondingly increased reduction in nodulation with the increase in the initial inoculum level. Raut (1980) reported that at all initial inoculum levels of M. incognita number of nodules per plant were significantly reduced in mung bacterized with Rhizobium. The maximum reduction was 75.5% over check in treatment receiving 1000 larvae. Taha & Kassab (1980) reported that inoculation of M. javanica with Rhizobium sp. did not affect nodulation on Vigna sinensis and nodules were also formed on the galls caused by M. javanica. Ali et al. (1981) observed more nitrogen deficiency and retarded cowpea growth of M. incognita and Rhizobium leguminosarum inoculated plants than in the absence of nematodes. Dhangar & Gupta (1983) noted that Rhizobium treated seeds showed better growth characters in

chickpea plants than untreated ones but there was no difference in pathogenic level in treated and untreated seeds when infected with M. javanica. Chahal & Singh (1984) reported that with the increase in the initial population of M. incognita there was corresponding decrease in number of nodules in pea plants having Rhizobium leguminosarum. Sharma (1984) observed greater reduction in number of nodules in pea when M. incognita and Rhizobium were inoculated together or when nematode had already established before the inoculation of Rhizobium as compared when Rhizobium had established before the nematodes. The nematode infection interfered with the symbiotic nitrogen fixation and reduced the nitrogen content of shoot and root.

(b) Cyst forming nematodes

Oostenbrink (1955) noticed that pea plants infected with Heterodera goettingiana possessed few nodules and exhibited poor growth. When nitrogen fertilizer was applied it compensated for the reduced nodulation in nematode infected plants. Ichinohe (1955) reported that soybean plants infected with H. glycines possessed more lateral roots without nodules than the healthy plants. Wardojo et al. (1963) observed that H. trifolii played a competitive role in reducing the number of nodules on white clover roots. Ross (1969) reported that H. glycines caused

reduction in soybean yield besides reducing root nodulation and nitrogen fixation. It incited deleterious host response that increased nitrogen deficiency. Barker & Huisingh (1970) reported greatest inhibition of nodule development (93-100%) in soybean when H. glycines and Rhizobium japonicum were inoculated together. Other treatments gave 0-90% reduction of nodulation. Barker et al. (1971) noted that concentration of nitrogen had a direct inhibitory effect on the activity of H. glycines. Simultaneous inoculation of nodulating and non-nodulating soybean with Rhizobium and H. glycines, as compared with nematode alone reduced number of cysts developing especially on nodulating soybean. Lehman et al. (1971) compared three races of H. glycines for their effect on nodulation and nitrogen fixation capacity of soybean. They reported that inoculum densities of 100, 200 and 400 crushed cysts per pot of race-1 of H. glycines and Rhizobium japonicum caused significant reduction in nodules per gm of root and nitorgen fixing capacity per plant as compared to Rhizobium japonicum check plants. The same inoculum densities of races 2 and 4 of H. glycines did not decrease nodules per gm of root or nitrogen fixing capacity per plant. Nodule number and nodule weight were inversely correlated with increasing densities of race 1. Race 1 caused severe chlorosis of soybean whereas race 2 and 4 did not. Barker et al. (1972) investigated that simultaneous inoculation of Rhizobium and

H. glycines caused greater inhibition of nodule development while 14 days delay in inoculation of nematode resulted in only slight to moderate inhibition. Race-1 of H. glycines which inhibited nodulation, penetrated nodular tissue at much faster rate than race-4 which had little effect. Hussey & Barker (1976) reported that under controlled condition in a phytotron H. glycines severely inhibited nodulation. Ko et al. (1983) made light microscopic studies to determine the step at which nodulation of soybean was disrupted by H. glycines. They reported that root hair responded to Rhizobium japonicum with tips curling, twisting or swelling despite extensive root infection of H. glycines. Rhizobium japonicum resulted in formation of only few nodules. Degeneration of bacteroid tissue appeared at 4 week, accompanied by the disappearance of starch in uninvaded cortical cells. Heterodera glycines most likely disrupted nodulation prior to the step of nodule initiation. Huang et al. (1984) observed that soybean lectin is involved in binding of R. japonicum to soybean root and H. glycines suppress the binding between roots and rhizobia. Scanning electron microscopy revealed that very few rhizobia were observed on the root surface of H. glycines infected plants. They concluded that reduction in binding to H. glycines infected roots apparently was due to the reduction in surface area of infected roots but resulted in interference of H. glycines with soybean lectin metabolism. Ko et al.

(1984) studied the effect of half root infection cf H. glycines race-1 on nodulation of soybean cv. Lee 68 in the presence of Rhizobium japonicum in the other half portion on the root. Nodulation was systematically and variously suppressed on both root halves of the split root plants five weeks after half root inoculation with 12500 eggs of H. glycines. Inoculation with 500 eggs caused suppression only on H. glycines infected root half while nodulation on the companion uninfected root half was stimulated slightly. They reported that systematic suppression of nodulation was reversible on the removal of H. glycines cysts. Ko et al. (1985) studied the structural changes by light and electron microscopy in developing soybean nodules as affected by H. glycines race-1. They noted that emerging nodules from cyst-nematode infected roots were poorly organized with less distinct zones of nodular tissues and early appearance of vascular elements and sclerenchyma layers. Massive accumulation of starch granules and crystalline arrays of phytoferritin in the plastids of cells in the nodular central tissues was the most conspicous feature in the infected plants.

(c) Concomitance of root-knot and cyst nematodes

Taha & Raski (1969) reported that inoculation of M. javanica and H. trifolii one week before, simultaneous or one week after inoculation of Rhizobium on white clover did

not hinder nodule formation. Nodule size did not differ in the nematode infected and nematode free plants. Formation of nodules on M. javanica galls and gall formation on nodules have been observed. Nematode infection did not disturb nodule structure and the nitrogen fixation efficiency of nematode infected nodules was not impaired. However, earlier disintegration of nodules as a result of M. javanica infection ultimately deprived the plants of nitrogenous materials. Sharma & Sethi (1976) reported that single or combined inoculation of M. incognita and H. cajani reduced the plant growth of cowpea while addition of Rhizobium reduced the damage to some extent. Individually, M. incognita caused more reduction in nitrogen content and root nodulation than caused by H. cajani. Both nematode species were found to thrive well and complete their life cycle on nodular tissues.

(B) Effect of migratory endoparasitic nematodes

Romaniko (1958) noted that Pratylenchus penetrans parasitized the nodules of peas, beans, vetch, peavine, alfalfa and red clover. Later, in 1961 he observed that P. globulicola also caused early destruction of nodules in peas, alfalfa and clover plants. Hussey & Barker (1974) described that Pratylenchus penetrans has little effect on nodulation and nitrogen fixation in soybean, peanut and cowpea. However, P. penetrans extensively damaged the

nodules of garden pea. Later, in 1976 they reported that P. penetrans stimulated nodule formation while inhibited nitrogen fixing capacity of soybean. In an experiment under controlled conditions in phytotron, plants inoculated with P. penetrans had more nodules per gm of root than nematode free plants. Germani et al. (1984) observed that Pratylenchus safaensis infestation in soybean reduced nodulation and nitrogen content. They suggested that harmful effect of P. safaensis is comparable to that of cyst or root-knot nematode as reported by Epps & Chambers(1962).

(C) Effect of semi-endoparasitic nematodes

Ayala (1962) observed that mature females of R. reniformis were attached to the bacterial nodules. Gupta & Yadav (1979) observed that R. reniformis infestation on Vigna mungo resulted in reduced nodulations as compared to control but the differences were insignificant. Taha & Kassab (1980) reported that inoculation of R. reniformis with Rhizobium did not affect nodulation on Vigna sinensis. They noted that nodule formation was hindered only when R. reniformis infection preceded rhizobial inoculation. Meredith et al. (1983) observed no evidence of bacteroid disruption by R. reniformis. Nematode infected soybean root nodules did not differ in shape and size from healthy ones. The section of nematode infected soybean nodule showed that R. reniformis penetrated into epidermis, root cortex, nodule

cortex and established permanent feeding site in the nodule endodermis and bundle endodermis.

(D) Effect of ectoparasitic nematodes

Malek & Jenkins (1964) reported that nodulation on vetch plants was reduced in the presence of Trichodorus christie and Criconemoides curvatum. Hussey & Barker (1974) observed that Belonolaimus longicaudatus stunted all hosts namely soybean, peanut, cowpea and garden pea but adverse effect on nodule number was observed only on soybean. The nodules that developed were longer and more efficient in fixing nitrogen than nodules on plants free from nematodes. Barker & Hussey (1976) investigated histopathology of nodular tissue and reported that the damage caused by B. longicaudatus on soybean and peanut was limited mainly on cortical tissues and in peanut this nematode caused premature senescence of nodules. Hussey & Barker (1976) reported that nodule formation of soybean was slightly reduced by B. longicaudatus. They concluded that influence of nematodes on nodulation of soybean varied according to their mode of parasitism.

Fungus root-nodule bacterium association

(A) Effect of Fusarium spp.

Twng-wah & Howard (1969) studied the role of Rhizobium japonicum as potential antagonist to F. oxysporum on soybean. The growth of Rhizobium is sensitive to

acidity, pH was choosen as a major environmental variable. Substrates buffered at pH 5.2 permitted severe root cortex necrosis by Fusarium, sparse rhizobial nodulation and no nodulation when rhizobium and Fusarium inocula were added simultaneously. At pH 7-7.6 rhizobial nodulation was good, root-rot was severe with Fusarium alone but reduced to trace or none in seedlings exposed concurrently to both organisms. Fusarium oxysporum with R. japonicum slightly reduced nodulation when compared with Rhizobium alone. Sawada (1982 and 1983) reported root discolouration and poor rhizobial nodulation of Lucerne seedlings when the soil was naturally infested with rhizobia and F. oxysporum. Severity of root-rot caused by F. oxysporum was less on nodulated than on non-nodulated plants. Multiplication of Rhizobium melioloti suppressed the hyphal growth of F. oxysporum in a mixed culture in vitro. Zambolim & Schenk (1984) reported that infection of Fusarium in soybean reduced the number and weight of R. japonicum nodules but the number of nodules increased in the presence of Glomus mosseae. There was no difference in growth response to G. mosseae and the pathogens between nodulated and non-nodulated plants.

(B) Effect of Rhizoctonia spp.

Orellana & Worley (1976) observed that inter and intracellular penetration by the hyphae of Rhizoctonia solani to young functional root nodules of soybean inoculated with R. japonicum was restricted to the outer

cortex. Penetration of the central tissue may have been impeded by a layer of sclerenchyma. Dysfunction in young nodules grown in the presence of R. solani may be due to toxic metabolites diffusing throughout the nodules. This dysfunction interfered with nitrogenase and symbiotic nitrogen fixation activities. Orellana et al. (1976) reported that R. solani significantly reduced the nodule weight of Lee and Kent soybeans inoculated with R. japonicum and grown in a N-free sand nutrient substrate as compared to plants grown with Rhizobium alone. Zambolim & Schenk (1984) reported that infection of Rhizoctonia in soybean reduced the weight and number of nodules but increased considerably in the presence of Glomus mosseae. There was no difference in growth response to G. mosseae and the pathogens between nodulated and non-nodulated plants.

(C) Effect of Phytophthora spp.

Chou & Schmitthenner (1974) reported that Phytophthora megasperma var. sojae killed more soybean plants in sterile soil in comparison to when Endogene mosseae and R. japonicum were present with this fungus. It was concluded that these two organisms may have a suppressive effect on root-rot severity. Gray & Hine (1976) observed that death of alfalfa seedlings was 24% higher when seeds were bacterized with R. japonicum than seedlings obtained from unbacterized seeds, in pasteurized soil,

artificially infected with P. megasperma. Increase in seedling death was not observed when treated or untreated seeds were planted in field soil naturally infested with P. megasperma and R. melioloti. Tu (1978) observed that severity of root-rot by P. megasperma was lessened when rhizobium was applied immediately after planting of soybean plants. Root-rot severity was found to decrease when the concentration of Rhizobium in soil was increased. The section of hyphae showed consistent bacterial presence inside the hyphae and indicated that rhizobia living saprophytically in soil may reduce root-rot by parasitizing hyphae of the fungus. The same author in 1980 reported that at a given concentration of Rhizobium the severity of root-rot increased with the increase in the fungus. However, increase in the concentration of rhizobia at a given fungal concentration decreased the degree of root-rot. Rhizobia protected alfalfa from winter kill by reducing severity of root-rot and increasing total nitrogen content. Beagle & Rissler (1983) reported that root-rot of soybean caused by P. megasperma f. sp. glycines was more severe on susceptible plants (Harosoy) nodulated by R. japonicum than on plants non-nodulated. Disease severity of resistant (Harosoy 63) did not differ in nodulated and non-nodulated plants. Fungus inoculated Harosoy plants had fewer nodules than did uninoculated Harosoy and Harosoy-63 plants. The fungus colonized the nodules of Harosoy but not of

Harosoy-63. Lower root nodule scores of fungus inoculated Harosoy plants might have been the result of destruction of both roots and root nodules by the fungus.

(D) Effect of Macrophomina sp.

Zambolim & Schenk (1984) reported that infection of Macrophomina in soybean reduced the number and weight of nodules of R. japonicum but increased considerably in the presence of Glomus mosseae.

(E) Effect of other fungi

Drapeau et al. (1973) observed antifungal activity of three Rhizobium isolates against eight different fungi. They reported that six fungi viz. Fusarium melanochlorum, Pyrenochaeta terrestris, F. culmorum, Colletotrichum destructivum, Phytophthora cactorum and Coniothyrium sp. were inhibted by Rhizobium while the growth of remaining two fungi viz., Rhizoctonia solani and Pythium ultimum was not affected. Gupta (1974) studied the effect of rhizosphere fungi on nodulation of Trigonella foenumgraecum and reported that all test fungi (Allternaria tenuis, Aspergillus luchuensis, A. nidulans, A. niger, Cunninghamella herbarum, Chaetomium sp., Helminthosporium sativum, Mucor luteus, Paecilomyces fusispora, Penicillium javanicum, P. citrinum, Rhizopus nigricans, Syncephalastrum racemosum, Thieloviopsis sp. and Trichoderma lignorum) either individually or concomitantly when mixed with sterilized soil, reduced the

number of nodules in comparison to control. However, M. luteus, A. niger, A. nidulans and Thielaviopsis sp. showed maximum inhibitory effect on nodulation. This inhibition may be due to secretion of toxic substances in the soil which indirectly reduced the number of nodules.

Role of lipid antioxidant in disease control

Lipid antioxidants, a heterogenous group of chemicals, are considerably cheaper than the common nematicides. It is believed that these chemicals are largely non-toxic and leave little or no residue. Lipid antioxidants have been used successfully in the control of atmospheric pollutants (Ormrod et al., 1976) and in nematode damage reduction (Mjuge & Estey, 1978; Siddiqui, 1988).

Nematodes (particularly root-knot nematode) oxidise lipids in the host root tissue which leads to the symptoms of aging in plants. It is believed that damage caused by root-knot nematodes can be reduced by protecting host plant roots with lipid antioxidants which inhibit lipid oxidation in plant roots. Oxidation of lipids in the roots is a must for root-knot nematode to be pathogenic. When lipids in the roots are not available nematodes use their own lipid reserves and this leads to decrease in nematode activity and infectivity. The nematodes start aging and later die.

Tonzig & Bracci (1951) reported that ascorbic acid application inhibited the formation of root nodules in

Pisum sativum L. Zuckerman et al. (1971) studied aging in Caenorhabditis briggsae under gnotobiotic condition and observed marked physiological aging by a decreased ability to withstand osmotic stress, a possible increase in the body's internal solute concentration and increased sensitivity to formaldehyde. They suggested that the ability to osmoregulate and the permeability of body wall are altered during senescence. During aging mitochondria of the hypodermis degenerated, some areas of thin hypodermis band thickened and lysosome like bodies formed in the interchordal hypodermis. Arrigoni et al. (1975) speculated that ascorbic acid would probably be implicated in defence mechanisms of plants. They experimentally varied the concentrations of ascorbic acid in tomato plants resistant and susceptible to Meloidogyne incognita and noted their reaction against nematodes. They (1975, 1977) observed that application of aqueous solution of lycorine, an alkaloid extracted from Sternbergia lutea Roem & Schult, decreased ascorbic acid in plant roots by inhibiting its synthesis. They concluded that a decrease in ascorbic acid in plants induced a reduction in their resistance to root-knot nematodes.

Castillo et al. (1975) studied the effects of two procaine preparations on Caenorhabditis briggsae and noted that concentration below 0.36 mM procaine had no significant effect on several developmental parameters of C. briggsae

such as growth, fecundity, time of inception of the reproductive period and duration of reproductive period. In old C. briggsae significant differences in osmotic fragility occurred in response to concentrations as below as 0.18 mM. They used ferritin for evaluating membranes negative surface charge. At 33 mM partial lysis of the cuticle surface membrane occurred and negative charge was lost from unlysed areas. At 7.2 mM negative charge was present in some areas of membrane but not in others, while at 0.18 mM negative charge density did not differ significantly from that of untreated nematodes. Some osmotic fragility effect persisted at procaine concentration which did not affect surface charge. This experiment suggested that procaine derivatives such as Gerovital H3 which delayed formation of the pigment of aging (lipofuscin), might have influenced the oxidation of lipids in the membranes of all functioning cells. Mjuge & Estey (1978) observed that infection of plants by root-knot nematodes is often accompanied by physiological changes characteristic of aging. Ultra-low tissue luminescence of infected plants indicated oxidation of cell membrane lipids. Cells with membrane subjected to oxidation lose some of their capacity of water retention. Treating tomato and radish with lidocaine hydrochloride an inhibitor of lipid oxidation retarded above ground symptoms of root-knot nematode infection and of aging. Fawole (1982) investigated the effect of lipid antioxidants such as

ascorbic acid and piperonyl butoxide in controlling M. incognita and the results were compared with the effect of DBCP. All the treatments reduced the number of nematodes but DBCP was more effective. Experiments with methionine, xylocaine, ascorbic acid and sodium benzoate (10, 100, 1000 and 10,000 ppm) showed inhibition in hatching and larval mortality. Methionine was more inhibitory to larval hatch than ascorbic acid, sodium benzoate and xylocaine. The same pattern was observed on larval mortality and both larval hatching and mortality, were concentration dependent. Siddiqui (1988) used one percent ascorbic acid solution as foliar spray, rootdip treatment for one hour and as soil application in three doses (10, 20 and 30 ml) for the control of root-knot nematode, M. incognita on tomato. Plants inoculated with 30 ml solution showed best improvement in plant growth and maximum reduction in nematode multiplication, followed by rootdip treatment. Inoculation of plants with 20 ml and foliar spray produced almost similar results. The treatment with 10 ml ascorbic acid was least effective.

Biological control

Biological control of nematodes includes the use of nematode trapping fungi, endoparasitic fungi that parasitize nematode eggs, females and cysts, bacteria, viruses, rickettsia and those microorganisms which produce

metabolites toxic to nematodes. Some of these organisms have been found quite useful for managing nematode populations as considerable information has been developed on this aspect of nematode control during the last 3-4 decades.

Kuhn as early as (1877) reported a fungus parasitizing females of Heterodera schachtii Schmidt, 1871. He named it as Tarichium auxiliarum Kuhn but later in 1881 he modified the species name to Tarichium auxiliare. Korab (1929) observed resting spores of the fungus inhabiting empty cysts and noted that this fungus grew in the mucilage present inside the cyst. He considered it of no consequence despite its frequent incidence. Jones (1945) also reported it from empty cysts of sugarbeet cyst nematode. Bursnall & Tribe (1974) also made similar observations. Tribe (1977a) placed it under the genus Catenaria as C. auxiliaris. This fungus was observed to parasitize the white females but did not attack the eggs. Birchfield (1960) recorded another species of this genus C. vermicola which was found parasitizing vermiform stages of plant parasitic nematodes including root-knot larvae.

Baunacke (1922) recorded three fungi namely Isaria destructor, Entomophthora calliphora and E. radicans from females of Heterodera species. Korab (1929) reported the presence of chlamydospores of an endomycorrhizal fungus, Glomus sp. (recorded as Protomyces) as well as a species of

Pythium from cysts of H. schachtii. Goffart (1932) recorded Cylindrocarpon radicicola from cysts of H. avenae.

Between 1950's to 1970's a number of other fungi were found parasitizing cysts or their contents. Thus Colletorichum atramentarium (Berkeley and Broome) Taubenhaus (C. coccodes (Wallroth) Hughes), Monotospora dalae (= Humicola grisea Traaen), Phoma tuberosa Melhus, Rosenbaum and schult (P. exigua Desmazieres), Pseudoeurotium ovale Stolk, Penicillium vermiculatum Dangeard, Anixiopsis stercoraria Hensen (= Xanthothecium peruvianum (Cain) Von Arx and Samson), and Margarinomyces heteromorpha Mangenot (Rhinocladiella mansonii (Castellani) Schol-schwarz) were isolated from unopened cysts of potato cyst nematode (Van der Laan, 1953 and 1956) and Phialophora malorum (Kidd and Beaumont) Mc Colloch from H. schachtii cysts (Van der Laan, 1956; Dowe, 1969). Another organism earlier recorded was a microsporidian parasite Dubosquia penetrans Thorne 1940, found attacking Pratylenchus brachyurus (Godfrey 1929) Goodey 1951 in U.S.A. (Thorne 1940). It was accepted as a protozoan parasite till its description as Bacillus penetrans by Mankau (1975a).

From mid seventies onwards the scientists became more interested in studying the possibility of management of nematode populations through these micro organisms. Life cycle of Bacillus penetrans appears to have remarkably adopted to parasitism of plant parasitic nematodes (Mankau &

Imbriani, 1975; Mankau & Prasad, 1977) and that of Paecilomyces lilacinus (Thom.) Samson on eggs of M. incognita acrita chitwood, 1949 and females of Globodera pallida (Stone, 1973) Behrens, 1975 (Jatala et al., 1979; Strattner, 1979). This fact gave impetus to more and more investigations of these micro organisms for use in biological control.

/ Jatala et al. (1979) tested the efficacy of a nematode parasitic fungus, Paecilomyces lilacinus, for the control of M. incognita acrita and Globodera pallida on potato. They noted that the fungus constantly infected eggs and occasionally famales of M. incognita acrita and also penetrated the eggs within the cysts of Globodera pallida and egg masses of M. incognita acrita in 10-20 days, grew and eventually destroyed the embryo in 80-90% of the eggs and fungus inoculated nematodes were found to be destroyed by the fungus. Jatala et al. (1980) reported that plants inoculated with P. lilacinus had significantly lower root galling index than those grown in plots applied with organic matter and nematicides. Eighty six percent of the egg masses collected from plants grown in the fungus treated plots were found infected with P. lilacinus and 54.7% of the eggs were destroyed. Jatala et al. (1981) studied the effect of multiple application of P. lilacinus in three consecutive crops of potatoes, bean and potatoes. This experiment was carried out in a field heavily infested with

M. incognita. They observed lower root and tuber root galling index in the first two crops from the fungus infested plots. There was however, no difference in the root galling index of the third crop grown in infested and non-infested plots. A careful examination revealed that non-infested plots were contaminated by P. lilacinus and there was no difference in the colony counted from samples obtained from all plots. Regardless of this contamination, there was significant reduction of nematode damage in all treatments. Apparantly an application of P. lilacinus was sufficient to establish the fungus and reduction of nematode population. Godoy et al. (1983) isolated four fungi namely Fusarium oxysporum, Paecilomyces lilacinus, Pseudopopulospora kendrickii and Verticillium chlamydosporium from single egg of Meloidogyne arenaria. Results of greenhouse studies indicated that P. lilacinus and V. chlamydosporium were effective in reducing the population of M. arenaria. Morgan-Jones et al. (1983) observed that Verticillium chlamydosporium prevented hatching in vitro and colonized eggs by hyphal penetration. Both the egg shell and larval cuticle were disrupted and the hyphae readily proliferated endogenously within the eggs and larvae. Mankau & Wu (1985) observed frequent association of Monacrosporium ellipsosporium with M. incognita egg masses and noted that six geographical isolates varied in their relative predacity towards the eggmasses of M. incognita.

In the preliminary test they observed that an aggressive isolate significantly protected tomato plants when grown in M. incognita infested soil and reduced the population of nematodes. In a second test of tomato in potted field soil inoculated with 1, 5 and 10 gm mycelium/15 cm pots, 15 days before nematode inoculation, showed significant reduction in plant damage at 5 and 10 gm levels, but none at 1 gm rate. Galling was reduced to 42% and 49% respectively in the 5 and 10 gm fungal treatments. Larvae in the soil and females/plant were also similarly reduced, but were same as control at the 1 gm rate. In a field experiment using two levels of the fungus on wheat grain substrate mixed into transplant holes for tomato seedlings, improved plant data and M. incognita reduction was also in direct relationship to the amount of fungus used, but treatments did not differ statistically from the control and protection was not substantial enough for dependable economic control. Morgan-Jones et al. (1984) observed parasitism of Meloidogyne arenaria eggs and larvae by P. lilacinus. They observed that hyphae of the fungus readily penetrated the egg shell through small pores dissolved in the vitelline layer. Invaded eggs became swollen as a result of change in shell permeability. Once, inside, a penetrating hypha enlarged, crushed the chitin and lipid shell layers in its immediate proximity, and permeated the egg content including the developing larvae whose cuticles were disrupted.

Endogenous hyphae re-emerged by tearing the egg shell and produced conidiophores bearing chains of conidia on the shell surface. The vitelline layer splitted into three discrete membranes which appeared unevenly thickened, the chitin layer became vacuolated and the lipid layer largely disappeared. Similarly, disorganisation of larval cuticle occurred and larvae became necrotic. Noe & Sasser (1984) reported that treatment with P. lilacinus increased the yield of tomato and okra. Population densities of M. incognita juveniles were lower at mid season of treated plots. Villanueva & Davide (1984) evaluated 14 isolates of soil fungi collected in Philippines mainly from M. incognita egg masses from tomato, egg plant and celery roots for the control of root-knot nematodes. Four isolates were identified as P. lilacinus. Another isolate was identified as Arthobotrys cladodes while other isolates were not identified as they had no activity against nematodes. All the isolates significantly reduced hatching. The local P. lilacinus isolates gave 63 to 82% reduction in gall formation when tomato seedlings were dipped in fungal suspension before inoculation with 300 or 1000 M. incognita eggs. Arthobotrys cladodes gave 49 to 79% reductions. Spore suspension of P. lilacinus had greater control efficiency than mycelial suspension while the reverse was true for A. cladodes. Dickson & Mitchell (1985) evaluated the potential of P. lilacinus alone and in combination with

Ethoprop and Fenamiphos for the management of M. javanica on tobacco in microplots and reported that P. lilacinus was an effective biocontrol agent for the management of M. javanica. Midha (1985) evaluated the efficacy of P. lilacinus for controlling root-knot infestation on cowpea and mung with three methods of inoculation namely egg masses, eggs and larvae. Fungal spores had some effect on treatments where inoculum source was eggmasses and eggs. Davide and Zorilla (1986) determined the effectiveness of P. lilacinus against M. incognita in a field experiment and concluded that the nematicide treatment reduced nematode population in soil more effectively than P. lilacinus treatment, resulting in comparatively better yield. However, no significant differences were observed in fruit weights among P. lilacinus and nematicide treated plants. Gaspard & Mankau (1986) isolated nematode trapping fungi from 43 of the 58 citrus orchards sampled. They noted that nematode trapping fungi were present in soils with and without Tylenchulus semipenetrans but were more numerous in soils containing the nematode. In addition to nematode trapping fungi the egg parasite, Dactyllela oviparasitica and endoparasite Cephalosporium balanoides were isolated from a single orchard. Khan & Husain (1986a) noticed that the females, eggs and juveniles of M. incognita collected from heavily infected brinjal roots were infected with Fusarium solani. The infected juveniles and adults were deformed

and thickly covered with fungal mycelium and chlamydospores. Since conidial stage was not found to develop on nematode hence it was concluded that M. incognita, though parasitized by F. solani, acts as a weak medium/host for fungal development. In another study (1986b) they evaluated the efficacy of different inoculum levels of P. lilacinus for the control of R. reniformis on cowpea. They observed that higher inoculum (1 or 2 gm/pot) of P. lilacinus significantly reduced plant damage due to R. reniformis. Sayre (1986) reported successful biocontrol of plant parasitic nematodes by fungal agents like Nematophthora gynophila, Dactyllela oviparasitica and P. lilacinus. Shahzad & Gaffar (1987) studied the effect of P. lilacinus alone and in combination with furadan against M. incognita on mung and okra. They observed significant reduction in root-knot infection in all treatments as compared to control on both the plants. Paecilomyces lilacinus alone and in combination with furadan gave good results as it reduced infection by more than 40% in mung and by about 60% in okra. Cabanillas et al. (1988) observed that root galling and giant cell formation were absent in tomato roots inoculated with nematode eggs infected with P. lilacinus. Few to no galls and no giant cell formation were found in roots dipped in a spore suspension of P. lilacinus and inoculated with M. incognita while numerous large galls and giant cells were present in roots inoculated only with M. incognita.

Paecilomyces lilacinus colonized the surface of epidermal cells as well as internal cells of epidermis and cortex. Khan & Husain (1988b) reported that application of P. lilacinus significantly reduced plant damage caused by either of the test pathogens singly or in combination. It also reduced nematode multiplication and root galling. It's efficacy was, however, more pronounced against monopathogenic than against multipathogenic infection. Paecilomyces lilacinus effectively reduced root-knot and reniform nematode populations by killing females, reducing their facundity and parasitizing egg masses. Paecilomyces lilacinus not only reduced the intensity of M. incognita and R. reniformis infections but also was antagonistic to R. solani. Sharma & Trivedi (1989) observed that P. lilacinus effectively controlled M. incognita under Indian agroclimatic conditions. They reported that there was 34, 75, 87 and 91% nematode reduction in plants treated with 1, 5, 15 and 75 gm of fungus infected rice grains respectively. The number of egg masses and number of eggs per eggmass were much lower in plants treated with fungus compared to controls.

Bursnall & Tribe (1974) observed 800 cysts of Heterodera schachtii from seven samples of English field soil. Verticillium chlamydosporium was the principal fungus isolated from 43 cysts, a sterile dark crystal forming mycelium from 21 cysts, Cylindrocarpon destructans from

20 cysts and black yeast from 13 cysts. Many isolates of V. chlamydosporium formed the dictyochlamydospores tardily and were first identified as Verticillium sp. Few Verticillium isolates did not form dictyochlamydospores. Willcox & Tribe (1974) examined populations of cysts of G. rostochiensis, H. schachtii and H. avenae from field soils for natural parasites. Of the 5078 cysts of G. rostochiensis from 20 sources, none was extensively or moderately diseased. Of the 587 cysts of H. avenae from 3 samples 13 cysts were apparently extensively diseased and these yielded Endogone. Of the 741 cysts of H. schachtii from two field soils 17 were extensively diseased. Single eggs from diseased cysts were isolated and those revealing fungal attack were plated on agar. Eggs from extensively diseased cysts of H. schachtii yielded a species of Cephalosporium. Reinfection of mature or developing cysts with the Cephalosporium showed a low degree of pathogenicity. Crump & Kerry (1977) reported that females of cereal cyst nematodes became infected within 2 to 25 days after rupturing root cortex and resting spores were produced approximately four days later. All the infected females eventually disintegrated and disappeared. When formalin was applied to soil at 2988 l/ha females were not attacked by the fungus but completed their development and produced cysts. The infective spores of the fungus that developed on attacked females were more important than resting spores

from the previous year in determining the proportion of females that became infected. Kerry & Crump (1977) observed that most populations of the cereal cyst nematode were parasitized by Entomophthora like fungus which killed females and caused break down of the cuticle preventing, cyst formation. This fungus attacked other cyst nematodes but not Globodera rostochiensis. Verticillium chlamydosporium was the most frequently observed egg parasite and killed 50% of eggs in females. Tarichium auxiliare and Cylindrocarpon destructans were found more frequently in soils. Tribe (1977a) reported that Catenaria auxiliaris a pathogen of females, was widespread in H. schachtii and uncommon in H. avenae whereas Entomophthora like fungi were widespread in H. avenae and rare in H. schachtii. Of the egg pathogens, Verticillium chlamydosporium and contortion fungus were common in H. schachtii and H. avenae and contortion fungus was also found in H. glycines. The minor egg pathogens were much less common. Tribe (1977b) reported that Tarichium auxiliare was widespread in populations of H. schachtii and also known in the cereal cyst nematode, H. avenae. Kerry & Crump (1980) observed Nematophthora gynophila (Leptolegniellaceae) parasitizing female nematodes which failed to form cysts as the fungus destroyed their body wall and cuticle eventually replacing the body contents with a mass of resting spores. A lagenidiaceous fungus was

reported which also killed female cyst nematodes. Kerry et al. (1980) observed greater survival of females on cereal roots and increased number of eggs/gm soil when the soil infested with H. avenae was drenched with formalin 2 weeks or more before planting. This was only due to control of fungi parasitic on females especially Nematophthora gynophila. Morgan-Jones & Rodriguez-kabana (1981) observed the presence of several specific fungal parasites as well as a population of miscellaneous incidental species associated with H. glycines on soybean. Fusarium oxysporum, F. solani and Exophiala pisciphila were implicated as major pathogens while Neocosmospora vasinfecta Phoma multirostrata and Verticillium leptobactrum were possibly involved in the degradation of cyst cuticle. Morgan-Jones et al. (1981) observed fungal colonisation of Heterodera glycines cysts in Arkansas, Florida, Mississippi and Missouri soil and found Fusarium gliocladium, Neocosmospora and Phoma commonly occurring in all localities. A species of Stagonospora which was found present in all four localities was believed to be a significant natural parasite of H. glycines eggs. Other fungi recovered were Chaetomium, Codineae heteroderae, Exophiala pisciphila, species of Thielavia, Verticillium lamellicola and a fungus referred as black yeast. Several other incidental fungi were found rarely. Kerry et al. (1982) reported that fungal parasitism is the major factor in limiting the multiplication of H. avenae. Approximately

60% of the females that failed to form cysts containing eggs can be accounted for infection of Nematophthora gynophila and Verticillium chlamydosporium. Grant & Elliott (1984) observed parasitism of H. glycines and Globodera solanacearum by fungi. Phialophora, Fusarium, Verticillium, Aspergillus, Monicillium, Gliocladium, Trichoderma, Rhizopus, Paecilomyces, Diheterospora, Chaetopsinia, Penicillium, Oiliodendron were isolated from H. glycines while species of Diheterospora and Trichoderma were identified in association with G. solanacearum cysts. The hyphae of Phialophora, Gliocladium, Aspergillus, Paecilomyces, Verticillium and Diheterospora penetrated through cuticle cyst walls and natural openings. Dackman & Nordrbring-Hertz (1985) observed 15 different fungi from different stages of nematode life cycle. Among egg parasites,, Verticillium chlamydosporium was common in young cysts on roots whereas an unidentified species of Verticillium (Verticillium sp. 1) was a dominating species in cysts from soil. Paecilomyces lilacinus, Macrodochium bolleyi, Cylindrocarpon sp. and several non-sporulating fungi were also isolated from eggs in cysts from soil. Between 10 to 20% of the eggs in cysts collected in the field were infected with fungi. In a pot test, between < 1 and 29% (mean = 13%) females on roots became always infected by Nematophthora gynophila. Francl & Dropkin (1985) observed that Glomus fasciculatum was a weak pathogen of

Heterodera glycines. Its hyphae (Missouri isolate) penetrated the female cuticle shortly after they ruptured the root epidermis. Glomus macrocarpum, G. mosseae and two isolates of G. fasiculatum were inoculated with H. glycines on plants of 'Essex' soybean. The Gfi isolate decreased the number of first generation adult females by 26% compared with non-mycorrhizal control. The total number of first generation plus second generation adult females were similar for both Gfi isolates and 29-41% greater than the non-mycorrhizal control. Roessner (1987) isolated four fungal isolates namely Cladosporium herbarum. Preussia sp., Fusarium oxysporum (1&2) from damaged eggs of Globodera rostochiensis and other partial egg parasites were tested for their efficacy against G. rostochiensis. Cladosporium herbarum was more effective than different strains of Verticillium chlamydosporium and Paecilomyces lilacinus.

Brown & Nardmeyer (1985) reported that combined effect of Pasteuria penetrans and carbofuran and aldicarb exceeded the sum of the effect of the bacterium and the effect of each nematicide alone. They concluded that carbofuran and aldicarb did not have detrimental effects on Pasteuria penetrans and demonstrated a synergistic reduction of root galling by M. javanica with these nematicides and bacterium. Bird & Brisbane (1988) observed the inhibition in the reproduction of M. javanica in presence of Pasteuria penetrans and adult females were found without eggmasses.

Other bacterium isolates from these soils had no inhibitory effect on M. javanica. Jay Raj & Mani (1988) reported that spore powder of Pasteuria penetrans at all concentration enhanced plant growth. Respective increases of 17.67, 19.95 and 14.32 in fresh and dry weights of shoots and fresh weight of roots were recorded at the concentration of 250 mg per kg soil. At 1000 mg/kg, 94.42% reduction was observed.

Broadbent et al. (1977) isolated Bacillus subtilis A13 from lysed mycelium of Sclerotium rolfsii. The strain A13 was inhibitory in vitro to several plant pathogens and had improved growth of many plant species in steamed and natural soils (Broadbent et al., 1971; Broadbent et al., 1977; Yuen et al., 1985). Burr et al. (1978) reported that strains of Pseudomonas fluorescens and P. putida when applied to seed pieces improved the growth of potatoes. Schroth & Hancock (1982) reported that fluorescent pseudomonads increased the yield of potato by 5-33%, of sugarbeet by 4-8 tons per hectare and root weight of radish by 60-144%. These strains and similar other strains were given the name of plant growth promoting rhizobacteria (PGPR). The term rhizobacteria was coined for bacteria with the ability to colonize root aggressively. Scher & Baker (1982) demonstrated the role of pseudomonads in the suppressiveness of certain soils to Fusarium wilt of flax, radish and cucumber. Arora et al. (1983) observed that

Pseudomonas fluorescens and P. putida were attracted to substances from conidia of Cochliobus victoriae and sclerotia of Macrophomina phaseolina. Stutz et al. (1986) also noticed the role of pseudomonads in suppressiveness of black root-rot of tobacco. Turner & Backman (1986) reported that Bacillus subtilis A13 increased the yield of peanut upto 37%. Cook & Weller (1987) reported management of take-all of wheat by pseudomonads.

Herbal control

(A) Effect of plant extracts on nematodes

Herbal control of plant parasitic nematodes has lately gained considerable importance. Plants (used as resistant varieties, trap crops, antagonistic plants for inter cropping and as rotation crop) and their products (e.g. oil cakes, green manuring with chopped parts, dried plant wastes, plant extracts and herbal nematicides) have been reported effective for management of nematode population in the soil and plant diseases caused by them. During the last two decades or so considerable work has been done to study the effect of extracts of different parts of a number of plants and their products on nematode mortality, hatching, penetration and consequently on disease development. Nematicidal properties of aqueous extracts of Anagallis arvensis (Nene and Thapliyal, 1966), Duranta repens, Solanum xanthocarpum, Argemone mexicana, Cucurbita pepo and

C. maxima (Husain & Saxena, 1969), Helenium sp., Gaillardia sp. (Gommers, 1972), Ageratum conyzoides, Allium sativum, Anacardium occidentale, Argemone mexicana, Calophyllum inophyllum, Citrus reticulata, Datura stramonium Hydnocarpus laurifolia, Holarrhena antidysenterica, Momordica charantia, Ocimum sanctum, Vernonia anthelmintica and Vinca rosea (Desai et al., 1973; Husain & Saxena, 1969; Husain, 1988a), Phaseolus vulgaris, Nicotiana tabacum (Miller et al., 1973), Zingiber officinale, Allium sativum, Capsicum annuum (Sukul et al., 1974), Curcuma longa (Pillai et al., 1975), Azadirachta indica, Chenopodium anthelminticum, Tagetes erecta, Aloe barbadense, Embelia ribes, Trichosanthes anguina, Momordica charantia, Jasminum arborescence, Tamarindus indica and Cuscuta reflexa (Husain & Masood, 1975), Azadirachta indica (Egunjobi & Afolami, 1976), Dephne odora (Kogiso et al., 1976), Chenopodium ambrosioides, Solanum hispidum, Melia azedarach, Cannabis sativa, Nicotiana tabacum, (Haseeb et al., 1978), Eclipta alba (Prasad & Rao, 1979; Husain, 1988a;) Allium sativum, Aegle marmelos (Satapathy & Das, 1979), Calotropis procera, Eclipta alba, Azadirachta indica, Cannabis sativa, Mentha piperita, Semecarpus anacardium, Rauvolfia serpentina, Trachyspermum ammi, Vernonia anthelmintica, Ocimum sp., Datura stramonium (Vijaylakshmi et al., 1979), Delphinium ajacis, Urtica urens, Eminium intortum, Papaver rhoeas, Citrullus colocynthis, Xanthium strumarium, Paganum harmala,

Brassica arvensis, Lepidium draba, Cephaloria syriaca (Mohammad et al., 1981), Tagetes jalisciensis (Castro & Munoz, 1982), Ocimum sanctum and Ocimum basilicum (Chatterjee et al., 1982), Mentha viridis, Emblica officinalis, Carissa caranda , Cassia fistula, Cordia myxa, Colocasia antiquorum, Dalbergia sisso (Haseeb et al., 1982), Tagetes microglossa, Tagetes jalisciensis (Munoz et al., 1982), Allium sativum (Nath et al., 1982), Amaranthus gracilis, Chenopodium album, Ricinus communis (Nandal & Bhatti, 1983), Ipomea carnea (Nikure & Lanjewar, 1983), Azadirachta indica, Hannoa undulata, Hannoa klaineana (Prot & Kornprobst, 1983), Calotropis procera, Nerium oleander, Euphorbia caducifolia, Flumeria oblongifolia, Ficus religiosa, F. elastica, Thevetia nerifolia, (Zurreen & Khan, 1984), Parthenium hysterophorus (Hasan & Jain, 1984), Leucaena leucocephala (Jain & Hasan, 1984), Eupatorium odoratum (Subramaniyan, 1985), Tagetes patula (Rajvanshi et al., 1985), Allium sativum (Gupta et al., 1985), Calotropis gigantea, Cuscuta reflexa (Vijaylakshmi & Goswami, 1985), Andrographis paniculata, Calendula officinalis, Enydra fluctuans, Solanum khasianum (Goswami & Vijaylakshmi, 1986), Cymbopogon flaxuosus (Tiyagi et al., 1986) etc. have been reported against several nematode species.

On the other hand, the extracts of Azadirachta indica, Chenopodium anthelminticum, Jasminum arborescence, Tamarindus indica, Tagetes erecta, Annona squamosa,

Aloe barbadensa, Phaseolus lunatus, Trichosanthes anguina, Momordica charantia, Cuscuta reflexa (Husain & Masood, 1979), Digitaria decumbens (Haroon & Smart, 1983), Parthenium hysterophorus (Hasan & Jain, 1984), Leucaena leucocephala (Jain & Hasan, 1984), Allium sativum (Gupta et al., 1985), Calotropis gigantea, Cuscuta reflexa (Vijaylakshmi & Goswami, 1985), Argemone mexicana, Datura metal, Eucalyptus globosus, Phyllanthus niruri, Calophyllum inophyllum, Madhuca indica, Shorea robusta (Goswami & Vijaylakshmi, 1986b), Ricinus communis (Dutt & Bhatti, 1986) Calotropis procera, Datura stramonium, Ricinus communis, Xanthium strumarium (Nandal & Bhatti, 1986), Cymbopogon flaxuosus (Tiyagi et al., 1986) have been reported to inhibit hatching of nematodes.

Some of the nematicidal plants have been used for improving crop production by controlling some major nematode pests. Gommers (1972) reported that under field and glasshouse conditions 24 plants of Heliantheae and Helenieae reduced Pratylenchus penetrans populations to very low level. Helinium and Gaillardia were found most effective. Johnson (1974) extracted a substance from oat straw and flax and tested it against M. incognita on tomato. He noted that no galls were formed on tomato roots when treated with alcohol extracts of 20 gm samples of undecomposed oat straw and flax. Sukul et al. (1974) used extracts of Zingiber officinale, Allium sativum and Piper nigrum (1 kg plant in

2.5 litre water and boiling it for 20 minutes) against M. incognita on Abelmoscus esculentus. Ten days after inoculation of M. incognita, 250 ml extract per pot was given thrice after 5 days interval in case of Piper nigrum while other extracts were given only once. Allium sativum extract killed most of the plants in 24 hours. Z. officinale extract caused temporary dropping and P. nigrum extract apparantly had no phytotoxic effect. Zingiber officinale and P. nigrum treatments gave significantly greater top weights and P. nigrum also significantly increased root weight. Nematode populations and root galls were considerably reduced. Egunjobi & Afolami (1975) reported that extract of Azadirachta indica (1.5, 1.0 and 0.5 kg/litre water) caused reduction in Pratylenchus brachyurus population from 30-71% on maize when applied in soil. The same authors in 1976 reported that boiled extract of Azadirachta indica without lime juice significantly reduced maize root population of P. brachyurus and increased grain yield, plant height and root weight. They noted strong correlation between increase in plant growth and yield, reduction in soil population and extract's concentrations. Prem Kumar & Nair (1976) reported that Eupatorium, Cympopogon citratus, Mangifera indica, Anacardium occidentale and Calotropis sp. @ 5000 kg per hectare, when applied in soil 21 days prior to sowing gave efficient control of root-knot nematode on okra.

Ram & Gupta (1980) used leaf extract of Azadirachta indica against M. javanica on chickpea and reported that highest dose (40 gm leaves in 25 ml of water/kg soil) resulted in best growth of plant. A positive correlation was found between the level of treatments and increase in fresh and dry weights of root. Chatterjee & Sukul (1981) reported that extracts of leaves of Peristrophe bicalyculata, Tragia involucrata and Anthocephalus kadamba and an aqueous suspension of oldrin significantly reduced root gall index, percentage of root protein and final population of M. incognita infecting Hibiscus esculentus compared to inoculated controls (800 larvae/pot). Nath et al. (1982) reported that the extracts of Argemone mexicana reduced M. javanica population by 29 to 64% on okra plants when applied in microplots. Husain et al. (1984) noticed that root-dip treatment of Solanum melongena seedlings with margosa and marigold leaf extracts resulted in considerably reduced development of M. incognita on it. Jain & Hasan (1984) reported that Koo-babool extract (prepared by adding 25, 50 and 100 gm leaves in 50 ml water/kg soil) increased plant growth of cowpea when applied against M. incognita. Application of extracts @ 100 gm leaves in 50 ml water/kg soil gave the best results and number of galls per plant was reduced considerably. Prasad et al. (1984) reported that extract of Eclipta alba reduced Meloidogyne graminicola females, egg masses and galls on rice plants. Significant

increase in shoot weight was associated with E. alba treatment. Bala et al. (1986) reported that aqueous extracts of leaves of Xanthium strumarium and Parthenium hysterophorus killed M. incognita larvae in 75 and 60 minutes respectively in in vitro tests. The extracts also promoted growth of okra plants infected with M. incognita and reduced number of root galls and final population of nematodes in the roots. Nandal & Bhatti (1986) found that gall formation was significantly reduced in brinjal plants treated with leaf extracts of Calotropis procera, Datura stramonium, Ricinus communis and Xanthium strumarium. However, the nematicidal efficacy of the extracts decreased with time, resulting in more galls after 45 days. Goswami & Vijaylakshmi (1986a) tested nematicidal properties of Andrographis paniculata, Calendula officinalis, Enydra fluctuans and Solanum khasianum against M. incognita on tomato and found that all of them reduced nematode population and galls. Calendula officinalis and Enydra fluctuans being more effective. Siddiqui and Alam (1987) reported that when seedlings of tomato, eggplant and okra raised from seeds treated with extracts of Azadirachta indica and Melia azedarach were inoculated with M. incognita or R. reniformis, the development of galls and the population of R. reniformis were significantly reduced. Husain (1988a) studied the effect of different plant parts of 22 different plants of Leguminosae and Compositae

families on the mortality, hatching, penetration and development of M. incognita on brinjal. He extracted a number of active principles including a new chromene compound from these plants and found them nematicidal and effective hatch inhibitors. He also observed that efficacy of some of these plants extracts was significantly enhanced if the plants were grown in oil-cake amended soil. Bhatti (1988) reported nematicidal activity of 205 different plants against 5 different nematodes. Achyranthus aspera and Phyllanthus niruri were most nematicidal followed by Croton sparsiflorus and Vernonia cinerea against M. javanica. Cirsium arvense was most nematicidal followed by Azadirachta indica, Ocimum sanctum and Tribulus terrestris against Anguina tritici. Calotropis procera was most nematicidal against T. semipenetrans followed by Cannabis sativa, Digera arvensis and Chenopodium album. Against Heterodera avenae, Achyranthus aspera and Cannabis sativa leaf extracts were nematicidal while against H. cajani, Oxalis corniculata and Solanum nigrum were most effective followed by Eucalyptus naundina and Ocimum sanctum. Leaf extracts of 21, 32 and 20 plants were screened for their effects of hatching of M. javanica, H. avenae and H. cajani respectively. Most of the plants inhibited larval hatching of M. javanica, H. cajani and H. avenae by 11.80-99.60%, 8.4-100% and 0.20-97.46% respectively. In general, extracts were thermostable and nematicidal action appeared to be a

Composite action of several compounds. He also analysed Xanthium strumarium, Chenopodium album, Chenopodium murale, Calotropis procera, Ricinus communis, Nerium oleander, Datura stramonium and Cymbopogon grasses chemically for rematicidal principles. The essential oils of X. strumarium, Cympbopogon grasses and methanolic extracts of the plants were found as active nematicides. Geraniol, methanol, cyclohexanol, their carbamates, acetates, butyrates and benzoates and cylohexanone, 3-chloro-p-menthane and p-3 menthene were found nematicidal against 2nd stage larvae of A. tritici, M. javanica and H. cajani.

Sangwan et al. (1985) observed nematicidal activity of essential oils of Cymbopogon grasses (C. martini var. motia, C. flexuosus and C. winterians). They noted that their major constituents such as geraniol, citrol, citronellol and citronellal were toxic to a varying degree against Anguina tritici, Tylenchulus semipenetrans, Meloidogyne javanica and Heterodera avenae. Kumari et al. (1986) observed toxic effect of water and methanolic extracts of leaves, stems and buds of Datura stramonium, Ipomea carnea, Tagetes patula and Lawsonia alba on the second stage larvae of Tylenchulus semipenetrans and Anguina tritici in vitro. They observed that methanolic extracts of leaves, stems and buds caused 75-100% larval mortality. In oil extracts from seeds of D. stramonium and L. alba it was 60-90%.

(B) Effect of plant extracts on fungi

Pariya and Chakraverti (1977) reported antifungal effect of extracts of different parts of Allium cepa, Euphorbia ligularia, Glycyrrhiza glabra, Embelia ribes and Tinospora cardifolia against Cochliobolus miyabeanus, Sclerotium rolfsii, Alternaria alternata and Aspergillus niger. They found that C. miyabeanus was totally inhibited by A. cepa bulb extract, S. rolfsii by T. cordifolia stem and root extracts, A. alternata by E. ribes seed extracts, G. glabra root and T. cordifolia stem and root extracts. Germ tube abnormalities, followed by lysis and disintegration, occurred in all fungi treated with E. liguralia extract. Chaumont and Jolivet (1978) reported that extracts of Vincetoxium officinale, Saponaria ocymoides, Aster alpinus, Chrysanthemum alpinum, Paris quardrifolia, Polygonatum, Verticilliatum, Digitalis grandiflora and Vernonica fructiculosa have inhibitory effect on Phytophthora cinnamomi, Graphium ulmi, Fusarium oxysporum, Chondrostereum purpureum, Rhizoctonia solani, Pestalotiopsis funerea and Alternaria radicina. Kumar et al. (1979) tested aqueous extracts of different parts of Allium cepa, A. sativum, Parthenium histopum and Phaseolus atropurpureus in vitro and reported that they completely inhibited spore germination of Setosphaeria rostrata, Fusarium oxysporum, Alternaria alternata and Corynespora cassiicola. Kapoor et al. (1981) tested the inhibitory effects of extract from

five species of Convolvulaceae on spore germination and mycelial growth of Alternaria brassicae, A. brassicicola and Fusarium oxysporum and found that the extracts of Convolvulus pluricaulis and Evolvulus alsinoides were almost completely fungicidal against these fungi. Bhowmick and Chaudhary (1982) studied antifungal activity of leaf extracts of ten medicinal plant species against Alternaria alternata and greatest inhibition in vitro was found from Acalypha indica followed by Vitex negundo and Azadirachta indica. Kishore et al. (1982a) reported that leaf extracts of Allamanda cathartica and Artabotrys hexapetala completely inhibited Colletotrichum falcatum and Rhizoctonia solani. Polyalthia longifolia was toxic only to C. falcatum. Kishore et al. in an other paper in the same year studied fungitoxic effects of leaf extracts of 22 plant species on Fusarium moniliforme. Leaf extract of Xanthium strumarium was found to be most effective against 22 plant pathogenic fungi. Pandey et al. (1982) reported that ethanolic extracts of Dodonaea viscosa, soybean, lentil, Leonotis nepetaefolia, Paspalum scrobiculatum and Peltophorum pterocarpum exihibited 100% activity against Alternaria alternata and marked activity against A. niger. Singh et al. (1983) reported that the fresh rhizomes of Zingiber officinale were toxic to Alternaria solani. Beek et al. (1984) reported antimicrobial activities of 19 Tabernaemontana spp. against several organisms including

Agrobacterium tumefaciens, Aspergillus niger and Candida albicans. Srivastava et al. (1984) studied antifungal activity of Parthenium hysterosphorus against Aspergillus fumigatus, A. niger, A. sulphureus and Microsporum gypseum. Singh & Singh (1984) suggested that the Zingiber officinale may be effective in controlling stem rot and wilt of Cicer arietinum caused by Sclerotinia sclerotiorum in the field. Vir & Sharma (1985) reported that at 2.5 and 5.0% concentration the extract from Azadirachta indica inhibited radial growth of Fusarium moniliforme by 57.8-66.7%, that of Aspergillus niger by 77.8%, Drechslera rostratum by 83.3-88.9% and that of Macrophomina phaseolina by 61.1-75.6%. Tripathi et al. (1986) reported that extracts from the plants of Iberis amara at young seedling stage were most toxic to Helminthosporium oryzae.

Culture filtrates

Since a large number of fungi naturally occur in the soil, they are expected to exert a negative or positive effect on other co-inhabiting soil micro-ortanisms including nematodes. When certain fungi are cultured in the medium, they produce some toxic metabolites in the culture medium. These toxic metabolites have been used successfully by different workers for nematode control (Mankau, 1969a,b; Desai et al., 1972; Khan et al., 1984a,b etc.).

Sherwood & Lindbergh (1962) reported that isolate 282 of Rhizoctonia solani growing in corn meal sand culture

produced a phytotoxic molecule with phenolic and glycosidic properties. There are also a number of reports demonstrating that toxic substances are produced in culture filtrate of R. solani (Newton & Mayers, 1935; Aoki et al., 1963). Mankau (1969a) reported that culture filtrates of Aspergillus niger contain quantities of oxalic acid lethal to Aphelenchus avenae. He observed that exposure of A. avenae to solutions of oxalic acid ranging from .0001 M to .005 M for 24 hr. caused mortality rates similar to culture filtrates. The toxic principle was also active after autoclaving indicating its thermolabile nature. Mankau (1969b) noted that 10 and 25% concentrations of A. niger filtrate immobilized 83 and 92% nematodes respectively in 12 hr. but the Fusarium filtrate was ineffective at all concentrations. Under these conditions Fusarium sp. was not toxic, and the inability of nematode to reproduce well may be attributed to the lack of one or more nutritional factors in the fungal protoplasm. Immobilized nematodes could not be revived when removed from A. niger filtrates and were dead. Aspergillus niger gave strong positive reaction to a spot test for oxalic acid. Sharma & Sharma (1969) and Sahni et al. (1974) reported that different species of Colletotrichum synthesized some toxic substances in the culture. Shukla & Swarup (1971) reported that fungus filtrate of Sclerotium rolfsii from its 10 days old culture inhibited larval hatch upto N/8 concentration

and was lethal to larvae upto N/4 concentration. Shoot weight of tomato increased significantly with the addition of 100 ml fungus filtrate to nematode infested soil. It was suggested that the lethal effect of filtrate on the nematode was not only due to pH but also due to some inhibitory substances present in the filtrate. Desai et al. (1972) studied effect of A. niger on root-knot nematode, M. incognita, and reported that maximum reduction in the disease was observed in the treatment with mixture of fungal filtrate and mycelium mat. The oxalic acid content in culture filtrate and mycelium mat was 8.7 and 2.5 percent respectively. That is why culture filtrate was found to be more effective in controlling disease than the mycelial mat in all the soil inoculations. Alam et al. (1973) studied the effect of culture filtrates of some fungi (Helminthosporium nodulosum, Trichoderma lignosum, Curvularia tuberculata, Penicillium caryophilum and Aspergillus niger), obtained from rhizosphere of okra, on the mortality of Hoplolaimus indicus, Tylenchorhynchus brassicae and larvae of Meloidogyne incognita. They also studied the effect of these filtrates on the larval hatch of M. incognita and found them to be nematicidal and hatch inhibitory to a varying degree. The lapse of time and higher concentrations increased this effect. Azam et al. (1979) reported that higher concentrations of culture filtrates of Rhizoctonia solani, Pythium sp. and

Collectorichum atramentarium inhibited the larval hatch and proved lethal to the larvae of M. incognita. The culture filtrates of Pythium sp. and C. atramentarium were more toxic to nematode larvae than to R. solani. Khan et al. (1984a) studied the effect of culture filtrates of eight species of Aspergillus on the hatching and mortality of M. incognita. They observed that A. niger, A. candidus, A. flavus and A. fumigatus were more toxic than other species and mortality was directly proportional to the concentration of filtrates and the duration of exposure. The S and S/2 concentrations of A. niger, A. candidus, A. flavus and A. fumigatus caused about 100% mortality within 12 hrs of exposure. The dilutions of A. niger (upto S/100) and of A. nidulans, A. terres, A. leuchuensis and A. glaucus (upto S/10) resulted in 100% mortality within 48 hrs. They speculated that differences in percentage mortality and larval emergence in culture filtrates of different species differed possibly because of differences in the nature of toxic metabolites produced by them. Khan et al. in another paper in the same year studied the effect of fungal filtrates of A. niger and R. solani on penetration and development of root-knot nematode and plant growth of tomato variety "Marglobe". They noted that root dip treatment with culture filtrates of A. niger and R. solani improved plant growth, moderately reduced larval penetration, suppressed nematode reproduction and gall

formation. Culture filtrate of A. niger was more effective than R. solani. Root dip treatment of tomato seedlings with A. niger filtrate for 30 minutes reduced the final larval population in soil to 1/2 of the initial population. Vaishnav et al. (1985) observed the effect of culture filtrates of Aspergillus spp. on M. arenaria and reported that nematode began to become inactive in six hours in all filtrates except that of A. flavus grown on Czapek's Dox broth. Culture filtrate of A. niger grown on potato dextrose broth for 20 days caused cent percent immobility in 12 hrs. while filtrates taken from 15 days old cultures caused cent percent immobility in 24 hrs. Culture filtrates from Czapek's Dox broth was less effective than the filtrate from potato dextrose broth. Culture filtrates of A. flavus grown on potato dextrose broth also immobilised the nematodes but not to the extent as that of A. niger. Walia & Swarup (1985) studied the effect of some fungi on nematode hatching and larval root penetration. Arthrobotrys oligospora inhibited hatching of M. incognita at all concentrations while Dactylaria brochopaga was effective only at 100 to 80 percent concentrations. Curvularia pallescence affected Heterodera zeae at 100 to 80 percent concentrations.

Screening

Screening of any crop variety aims to evaluate it for tolerance/resistance against a given level of a particular

nematode under a specific set of conditions. Isolation or identification of a resistant variety is likely to serve as a resistant donar parent or it may be used as a commercial variety for cultivation. Growing of a resistant cultivar is the cheap and best method of nematode control because it requires no special equipment or extra capital investment. Resistance in relation to nematode can be defined as "the ability of the plant to discourage feeding or inhibit penetration and/or to interfere with the completion of the nematode life cycle under a particular set of condition". Plant exudates and the chemical constituents of the cells of the preferred infection site are generally responsible for inhibiting penetration and discouraging feeding while the altered host physiology at the infection site after initial penetration (formation of phytoalexins) interfere with the completion of nematode life cycle because the endoparasitic nematodes after their entry may die at the later developing stages or the sex reversal may take place which results in the development of more males (which generally do not parasitize) than females thereby significantly reducing the inoculum level to cause significant damage.

Different reactions of a crop variety against a particular nematode, as some times observed at different places may either be due to the involvement of different biological races of the same nematode at different places or the non-homogenous nature of the crop variety to nematode

reaction although it may be phenotypically homogenous or the use of the different level of inocula and soil types or due to temperature variations under different sets of experimental conditions.

Considerable work has been done on the varietal screening of pulse crops against different nematodes. In the following paragraphs is presented a review of the work done on chickpea, Cicer arietinum L.

Sandhu et al. (1981) studied the reaction of 157 improved strains and 5 local varieties of chickpea against Meloidogyne incognita under field condition and reported that all varieties tested were susceptible to it to a varying degree. Most cultivars tested had a percentage of root-knot between 60-80 but strain 7077 had minimum infection i.e. 8.7%. Mani & Sethi (1985) screened 55 varieties of chickpea against M. incognita and reported that selection No-501 was resistant with gall index rating of 2. Eighteen varieties were moderately resistant while all others were susceptible or highly susceptible. Mishra & Gaur (1989) screened 540 chickpea varieties against M. incognita and reported that none of them gave an immune reaction. Fifteen varieties namely ICC Nos. 4954, 5485, 6444, 7200, 7209, 7578, 8556, 8565, 8739, 8748, 12245, 12255, GL-83011, K-904 and BG-217 gave resistant reaction; 316 lines exhibited moderately susceptible reaction while

194 lines and 18 lines gave susceptible and highly susceptible reactions respectively.

Khan & Khan (1987) studied the reaction of five cultivars of gram to root-knot nematodes, M. incognita race-1 and M. javanica and noted that all the cultivars were attacked by both nematodes and plant growth was adversely affected. All the cultivars were susceptible to both nematode species but 2 were hypersusceptible to M. javanica. Sasser et al. (1987) screened 45 accessions from ICRISAT against M. incognita races 1, 2 & 3, M. arenaria race-2 and M. javanica. Another 50 accessions were screened against four major species of Meloidogyne and their respective host races. Although occasional accession were identified as tolerant to a few species or races, the vast majority were susceptible to all the nematode populations against which they were evaluated. Thakar et al. (1987) studied the reaction of 17 chickpea varieties against M. incognita and M. javanica. They reported that no variety was found immune or resistant. The variety pulse G5 was moderately resistant while others were susceptible.

Protein changes in diseased plants

When plants are infected by pathogens, the proteins in the penetrated plant cells are changed chemically and physically. Some enzymatic proteins are produced in the

penetrated cells by pathogens themselves. Thus qualitative and quantitative changes in proteins occur in the penetrated plant cells, and the origin of proteins are related to both plants and pathogens.

The non-infected tissue adjacent to infected tissue shows changes in metabolism that involve stimulation of synthesis and degradation of specific proteins. Enzymatic reactions are also influenced by changes in concentrations of activators, inhibitors and effectors as well as substrates and coenzymes in response to infection. Such changes in enzymatic reactions should be concerned with protein changes.

Cell organelles, such as mitochondria, are also changed qualitatively and quantitatively in both infected and nearby non-infected tissues. These changes are directly associated with those in enzyme complexes and are involved in protein changes.

Akazawa & Uritani (1956) reported that protein contents are increased 10-30% in cut-injured tissue by 24 hr after incubation compared to fresh tissue, when it is assayed from trichloroacetic acid (TCA) insoluble fraction. Uritani & Stahmann (1961) making use of electrophoretic and immunochemical technique and analysis of microsomal components showed increase in proteinaceous components of infected tissues. Littrell (1966) observed cellular

response of Hibiscus esculentus to M. incognita and reported that total protein and ribonucleic acid accumulated in giant cells and in the bodies of nematode and by 26 days following inoculation were greater than occurring in adjacent tissues. Sharma et al. (1980) observed accumulation of total phenols, proteins and proline in the infected roots with M. incognita alone and in combination with Rhizoctonia bataticola over healthy roots while total sugars were decreased in infested roots. Chatterjee & Sukul (1981) reported total protein content of galled roots as an index of root-knot nematode infestation of lady's finger plants. They noted that gall index number which reflected the degree of nematode infection was positively correlated with the percent total protein in galled host plants. The root gall indices were also positively correlated with the nematode population. They concluded that the quantity of total galled root protein thus gave a measure of the degree of M. incognita infection. Arya & Tiyagi (1982) observed changes in total protein in three carrot cultivars infected with M. incognita The healthy roots of resistant cultivar Black, stained strongest for total proteins. However, there was further increase in protein content in infested roots. Galls in other cultivars (Ecarlynantes and Pusakesar) also showed accumulation of protein but it was less than in the resistant cultivar. Basu & Sukul (1983) observed changes in total protein, carbohydrates and lipid in the roots of

Hibiscus esculentus resulting from infection of root-knot nematodes. They reported that total protein, carbohydrates and lipid in roots increased in amount with the growth of both inoculated and uninoculated test plants. The inoculated plants had always higher amount of protein but lower amount of carbohydrates and lipid in roots than the uninoculated ones. The root carbohydrate and root lipid which are thought to be reduced due to feeding by nematodes, provide additional biochemical parameters for evaluating intensity of infection with root-knot nematodes. Upadhyay & Banerjee (1986) studied some biochemical changes in chickpea plants infected with M. javanica and noted that protein content in both roots and stems of the attacked plants increased over uninoculated check. The increase was more pronounced in stem than in root which was ultimately dependent upon the level of infection. The increase in roots ranged from 10.638 to 17.021 percent and in stem from 14.586 to 17.899 percent over control. Similarly total amino acid contents increased with the level of infestation. It varied from 37.504 to 54.545 and 26.315 to 54.545 percent in stem and root over control respectively. Sugar contents, chlorophyll a and b showed decreasing trend due to root-knot nematode infection. Simte & Dasgupta (1987a) observed sequential changes in proteins of soybean, inoculated with root-knot nematode, M. incognita. Inoculated roots showed higher concentration of total buffer soluble protein over their respective control.

Changes in peroxidase activity

Peroxidase is known as one of the key enzyme required for lignin synthesis and lignin is one of the compound judged to be phytoalexin which plays a decisive role in resistance. Peroxidase catalyzes several reactions including those involved in metabolism of phenols and indoles. The implication of phenols in symptom expression resulting from plant nematode interactions make it more meaningful to have a look on the role of this enzyme in disease syndrome.

Loebenstein & Linsey (1961) observed that peroxidase activity of both leaves and roots was significantly higher in sweet potatoes infected with vein clearing virus than in healthy ones. Increase in peroxidase activity following inoculation commences with the appearance of symptoms in the infected plants. Fehrman & Diamond (1967) observed a positive correlation between peroxidase activity in different organs of potato plant and resistance against Phytophthora infestans. There was some corrrelation between the resistance of tissue and activity of polyphenol oxidase. Veech & Endo (1970) demonstrated an increase in activity of cytochrome oxidase and peroxidase in soybean infected with root-knot nematode, M. incognita. Daly et al. (1971) reported that resistance to race-56 of Puccinia graminis in wheat (controlled by the Sr 6 and Sr 11 alleles) resulted in higher peroxidase activity. However, the increased activity

was believed not to be the cause of resistance mechanism. Giebel et al. (1971) reported high activity of peroxidase, tyrosinase and glucosidase in necrotic cells of roots of resistant plants. Shannon et al. (1971) reported rapid post infectional increase in peroxidase activity resulting from de novo synthesis of enzyme or activation of pre-existing inactive form of enzyme. Acedo & Rohde (1971) observed that peroxidase activity increased in roots of cabbage (Brassica oleracea) infected by Pratylenchus penetrans. Hussey & Krusberg (1970) reported that Ditylenchus dipsaci induced qualitative differences in multiple form of peroxidase of wando pea (Pisum sativum) while Huang et al. (1971) detected qualitative differences between peroxidase multiple forms of uninfected and galled stem of tomato (Lycopersicon esculentum) but not between uninfected and galled roots. Noel & Mc Clure (1978) studied peroxidase and 6-phosphogluconate dehydrogenase in resistant and susceptible cotton infected by M. incognita. They observed that 6 days after inoculation specific activity of 6-phosphogluconate dehydrogenase and peroxidase were greater in infected than in uninfected roots and also were greater in resistant cultivar 'Clevewilt 6-3-5' than in suceptible cultivar 'M8'. In uninfected roots, peroxidase activity was greater in 'Clevewilt' roots than in 'M8' roots, but the activity of 6-phosphogluconate dehydrogenase was the same. Mote & Dasgupta (1979) provided positive evidence for de

novo synthesis of enzymes of phenylalanine ammonialyase associated with resistant expression in tomato against M. incognita. Likewise Ganguly & Dasgupta (1981) noted possible de novo synthesis of isozymes of peroxidase, ribonuclease and protein components in root-knot disease of tomato by M. incognita. Mohanty et al. (1986) investigated the development of peroxidase activity at two intervals in two cowpea cultivars viz. Pusa Barsati (susceptible) and C-152 (resistant) inoculated with root-knot nematode, M. incognita. Quantitative increase in peroxidase activity was observed at both intervals (15 and 30 days). On the basis of electrophoretic analysis, it was found that new isozyme of peroxidase was synthesized during post infection period. Simte & Dasgupta (1987b) suggested that elevated level of peroxidase activity in soybean var. Clark-63 with M. incognita was due to de novo synthesis of peroxidase isozymes.

MATERIALS & METHOS

Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949 race-3 and Macrophomina phaseolina (Tassi) Goid were used as test pathogens and chickpea (Cicer arietinum L.) variety P-256 as test plant throughout the course of these investigations.

Preparation and sterilization of soil mixture

Sandy loam soil sieved through 16 mesh sieve, river sand and organic manure were mixed in the ratio of 3:1:1 and 6" clay pots were filled with soil @ 1 kg/pot. A little water was poured in each pot just to wet the soil before transferring pots to an autoclave for sterilization at 20 lb pressure for 20 minutes. Sterilized pots were allowed to cool down at room temperature before use for experiments.

Raising and maintenance of test plants

Seeds of test plant, surface sterilized with 0.1% mercuric chloride for 2 minutes and washed thrice with distilled water, were treated with chickpea strain of Rhizobium before sowing. Sucrose solution was used as sticker for bacterization. Five bacterized seeds were sown in each pot but after germination one seedling per pot was maintained. Watering was done whenever required. One week old, well established and healthy seedlings were used for experimental purposes.

Preparation of nematode inoculum

Large number of egg masses from heavily infected brinjal roots were hand picked with the help of sterilized forcep from the previously maintained pure culture of M. incognita race-3. The egg-masses were washed with distilled water and placed in a sieve containing crossed layer of tissue paper. The sieve was placed in a petridish containing water just touching its lower portion. A series of such assemblies were kept to get required number of second stage juveniles for inoculation. The hatched out larvae were collected from petridishes after every 24 hours and transferred to a beaker. Fresh water was added to the petridishes to repeat the process. Counting of nematodes was done from the collected suspension of nematodes. An average of 5 counts were made to determine the density of nematodes in the suspension. The volume of nematode suspension was so adjusted that each ml may contain 100±2 nematodes.

Isolation of fungus from infected chickpea roots

Chickpea plants showing distinct galls and exhibiting root-rot symptoms were collected in polythene bags from infected fields.

Serial washing technique was employed to isolate fungus from infected roots. Roots were transferred to an

sterilized dish containing sterilized distilled water and gently freed of soil particles. The roots were then transferred to another dish and process was repeated till such time that all the adhering soil particles were removed. Later, the roots were cut into approximately 5 mm pieces and transferred to petridish containing 0.1% mercuric chloride solution. After one minute root pieces were washed atleast thrice in distilled water and dried on filter paper. Five of these root pieces were then plated in each of 10 petriplates containing PDA, with the help of sterilized forcep under aseptic condition. Petriplates were incubated at 28±2°C for 10 days. The fungus that developed on root segments was examined and identified. On confirmation of its identity as Macrophomina phaseolina, its pure culture was prepared.

Raising and maintenance of fungal culture

For obtaining sufficient inoculum the fungus was later cultured on Richard's liquid medium (Riker & Riker, 1935) having following composition.

Potassium nitrate	10.00 gm
Potassium dihydrogen phosphate	5.00 gm
Magnesium sulphate	2.50 gm
Ferric chloride	0.02 gm
Sucrose	50.00 gm
Distilled water	1000.00 ml

The medium was prepared and filtered through muslin cloth, sterilized in an autoclave at 15 lb pressure for 15 minutes in 250 ml Erlenmeyer flasks each containing 80 ml liquid medium.

The fungus was inoculated in each flask with the help of inoculation needle. Inoculated flasks were incubated at 28±2°C for about 15 days to allow sufficient growth of the fungus. Pure culture was continuously maintained on PDA by reinoculation of the fungus after every 15 days.

Preparation of fungal inoculum

After incubating the flask for about 15 days the liquid medium was filtered through whatman filter paper No. 1. The mat was washed in distilled water and excess of water was removed with the help of blotting paper. The inoculum was prepared by mixing 10 gm fungal mycelium in 100 ml of distilled water and blending it for 30 seconds in a mixer. The 10 ml of this suspension was inoculated having 1 gm fungus.

Inoculation technique

One week old chickpea seedlings were inoculated with 2000 second stage juveniles of M. incognita and 1 gm mycelium of M. phaseolina throughout the course of these investigations. Feeder roots of seedlings were exposed just

before inoculation by carefully removing the top layer of soil and required quantity of inoculum was poured uniformly all around the exposed root using sterilized pippete. Exposed roots were immediately covered by levelling the soil properly.

Both, individual or simultaneous inoculation of different pathogen combinations was done depending upon the experiment. Throughout these studies each treatment was replicated thrice and uninoculated plants were kept as control. Watering was done whenever required. Experiment was terminated after 90 days of inoculation unless stated otherwise.

EXPERIMENTS

1. Determination of inoculum threshold

In order to determine the inoculum threshold of M. incognita the seedlings of chickpea variety P-256 were inoculated with 500, 1000, 2000, 4000 and 8000 second stage juveniles. Similarly, seedlings were inoculated with 0.25, 0.50, 1.00, 2.00 and 4.00 gm mycelium of M. phaseolina for determining fungal inoculum threshold level. Since inoculation of plants with 2000 juveniles of M. incognita or with 1 gm M. phaseolina caused significant reduction in growth and nodulation even at P= .01, these inoculum levels were used in subsequent studies, unless stated otherwise. Peroxidase activity and buffer soluble proteins in the root

and shoot of similarly treated plants were also estimated after 45 days of inoculation using standard methods described on subsequent pages.

2. Studies on interaction of different inoculum levels of test pathogens

Various combinations of concomitant inoculations of the test pathogens using different inoculum levels were designed in the manner shown in Table A .

3. Studies on individual, simultaneous and sequential inoculation of test pathogens

In order to study the effect of early establishment of either of the pathogen, chickpea seedlings were inoculated with 2000 juveniles and 1 gm fungus individually and in various combinations of simultaneous, pre and post inoculation. Effect of Rhizobium in various combinations was also studied.

For preparing rhizobial inoculum 100 gm commercial bacterial culture of chickpea strain was dissolved in 1000 ml of sterilized distilled water, 10 ml from this suspension having 1 gm rhizobial inoculum was added. Inoculations were made as per schedule presented in Table B.

4. Screening of chickpea varieties

Sixty five varieties (Gora Hissar, L-144, Annegiri, Avrodhi, C-235, BGM-417, K-850, JG-315, GNG-146, Gaurav,

Table A

S.No.	Nematode inoculum *M. incognita* (No. of nematode/pot)	Fungal inoculum *M. phaseolina* (gm mycelium/pot)
1.	Control	Control
2.	500	-
3.	1000	-
4.	2000	-
5.	4000	-
6.	8000	-
7.	-	0.25
8.	-	0.50
9.	-	1.00
10.	-	2.00
11.	-	4.00
12.	500	0.25
13.	1000	0.25
14.	2000	0.25
15.	4000	0.25
16.	8000	0.25
17.	500	0.50
18.	1000	0.50
19.	2000	0.50
20.	4000	0.50
21.	8000	0.50
22.	500	1.00
23.	1000	1.00
24.	2000	1.00
25.	4000	1.00
26.	8000	1.00
27.	500	2.00
28.	1000	2.00
29.	2000	2.00
30.	4000	2.00
31.	8000	2.00
32.	500	4.00
33.	1000	4.00
34.	2000	4.00
35.	4000	4.00
36.	8000	4.00

Table B

S.No.	Treatments
1.	Control Bacterized
2.	Control Unbacterized
3.	MI
4.	MP
5.	MI + MP
6.	MI + RH
7.	MP + RH
8.	MI + MP + RH
9.	MI ⟶ RH
10.	MP ⟶ RH
11.	MI + MP ⟶ RH
12.	RH ⟶ MI
13.	RH ⟶ MP
14.	RH ⟶ MI + MP
15.	RH + MP ⟶ MI
16.	RH + MI ⟶ MP
17.	MI ⟶ RH + MP
18.	MP ⟶ RH + MI

MI = Meloidogyne incognita; MP = Macrophomina phaseolina;
RH = Rhizobium; + = Simultaneous inoculation;
⟶ = Inoculation 10 days prior

ICC-7002, BG-244, H81-73, BGM-408, P-256, IC-4918, IC-4919, IC-4920, IC-4921, IC-4922, IC-4923, IC-4924, IC-4925, IC-4926, IC-4927, IC-4928, IC-4929, IC-4930, IC-4931, IC-4932, IC-4933, IC-4934, IC-4935, IC-4937, IC-4938, IC-4939, IC-4940, IC-4941, IC-4942, IC-4943, IC-4944, IC-4945, IC-4946, IC-4947, IC-4948, IC-4949, IC-4950, IC-4951, IC-4952, IC-4953, IC-4954, IC-4955, IC-4956, IC-4957, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4963, IC-4964, IC-4965, IC-4966, IC-4967 and IC-4968) of chickpea were screened against M. incognita and M. phaseolina individually.

The degree of resistance and susceptibility of different cultivars was determined on the basis of following three parameters.

(1) Percentage reduction in dry shoot weight alongwith root-knot, root-rot indices and nematode reproduction.

(2) Percentage increase/decrease in peroxidase activity.

(3) Percentage increase/decrease in buffer soluble protein.

Peroxidase activity and protein content in shoots of 65 varieties were determined when infected with M. incognita and M. phaseolina singly.

Peroxidase activity

Peroxidase activity of control and infected plants (after 45 days of inoculation) was determined by the method of Chance & Maehly (1955).

Extraction

200 mg fresh leaves were homogenized in 10 ml of 0.1M phosphate buffer pH 6.8 and centrifuged at 2°C for 15 minutes at 17000Xg. The clear supernatant was taken as enzyme source.

5 ml of the assay mixture for the peroxidase activity was having 125µ moles of 0.1M phosphate buffer pH 6.8, 50µ moles of pyrogallol, 50µ moles of H_2O_2 and 1 ml of the enzyme extract diluted 20 times.

It was incubated at 25°C for 5 minutes after which the reaction was stopped by adding 0.5 ml of 5% (V/V) H_2SO_4. The amount of purpurogallin formed was determined by noting the absorbance at 420 nm. A calibrated standard curve was plotted by graded concentration of pure purpurogallin. The specific activity of peroxidase was calculated by purpurogallin formed per mg protein per minute.

Protein estimation

Concentration of soluble protein in crude extract was determined by the method of Lowry et al. (1951). One ml centrifuged supernatant (as used in peroxidase) was taken and to this was added 5.0 ml of freshly prepared copper reagent (prepared by mixing in 1:50 ratio of 0.5% (W/V) copper sulphate in 1% sodium potassium tartrate and 2.0% (W/V) sodium carbonate in 0.1M sodium hydroxide). After incubation at room temperature for 10 minutes, 1 ml of 1N Folin phenol reagent was added and tubes were instantly vortexed. Absorbance of developed blue colour was measured after 30 minutes at 660 nm against a reagent blank. The amount of protein in a sample was determined from the standard curve using bovine serum albumin. Percentage increase in protein content was calculated.

5. Studies on the effect of ascorbic acid & P. lilacinus

For this experiment 0.1% solution of ascorbic acid was prepared in distilled water and following treatments were

given when plants were inoculated with any one or both the test pathogens.

(A) Seed treatment for 12 hrs.

(B) Foliar spray 6 times after every 10 days from the day of inoculation.

(C) Soil application of 5, 10 and 20 ml at the time of inoculation of pathogen/pathogens.

Similarly, 3 doses (0.5, 1.0 and 2.0 gm) of P. lilacinus inoculums were also used.

6. Studies on biological & herbal control

The fungus, Acrophialophora fusispora was cultured on sand maize (1:1) medium and used in 5, 10 and 20 gm doses. Paecilomyces lilacinus was cultured on Richard's liquid medium and was given in 0.5, 1.0 and 2.0 gm doses while Bacillus licheniformis and Alkaligenes faecalis were cultured on nutrient agar medium. The bacterial growth was scrapped and dissolved in distilled water to obtain $10x10^8$ concentration of bacterial cells per ml and 5, 10 and 20 ml doses of these two bacteria were applied. All the four biocontrol agents were used for the control of both individual and concomitant infections of the test pathogens.

Leaf extracts of Cymbopogon citratus, Eichhornia crassipes and Ipomea carnea were obtained by chopping fresh

leaves and macerating in a blender at high speed (1 kg leaves per 500 ml distilled water) till they were fully crushed. The extract was obtained by squeezing through double layered muslin cloth and centrifuged at 6000 rpm for 15 minutes. Efficacy of these extracts was tested using three soil doses of 5, 10 and 20 ml per plant when applied at the time of inoculation both in case of single and concomitant inoculations.

7. Studies on the effect of culture filtrates of some soil fungi

Aspergillus niger, A. flavus, Alternaria brassicicola, A. triticina, Fusarium solani and Paecilomyces lilacinus were grown for 15 days in 150 ml Richard's medium. Fungal filtrates of above mentioned fungi were obtained by filtering through whatman's filter paper No. 1. Filtrates thus obtained were centrifuged at 6000 rpm for 15 minutes and were taken as standard solution 'S'. A ten fold dilution of each filtrate was also prepared and these two concentrations (S and S/10) were tested for their efficacy against single and concomitant inoculations.

Recording of observations

Plants were uprooted after 90 days of inoculation except stated otherwise. Root systems were gently washed of soil taking utmost care to avoid losses and injury during

the entire operation. For measuring length and weight, the plants were cut with sharp knife just above the base of root emergence zone. Length of shoots and roots were recorded in centimeters from the cut end to the top of the first leaf and longest root respectively. The excess of water was removed by putting them between two folds of blotting sheets for some time before weighing them separately. The weight was recorded in gm. For dry weight the roots and shoots were kept in envelops for drying in an oven at 60°C for 2-3 days. Reduction in dry shoot weight was calculated in terms of percentage reduction for interpretation of results.

Root nodule estimation

Nodulation was estimated by counting the number of nodules per root system and percentage nodulation reduction was calculated.

Rating of resistance and susceptibility

Resistance/susceptibility ratings were done on the basis of reduction in dry shoot weight and nematode reproduction according to the following scales as proposed by Husain (1986) with a slight modification.

(A) Against nematode

0 = No galling, no nematode reproduction, no reduction in dry shoot weight. Immune

1 = 1-10 galls, Rf = < 1, dry shoot weight reduction upto 5% Resistant

2 = 11-20 galls, Rf = 1.01-2.00, dry shoot weight reduction 5.01-10% **Moderately resistant**

3 = 21-30 galls, Rf = 2.01 to 4.00, dry shoot weight reduction 10.01-15% **Tolerant**

4 = 31-100 galls, Rf = 4.01 to 7.00, dry shoot weight reduction 15.01-25% **Susceptible**

5 = More than 100 galls, Rf = > 7, dry shoot weight reduction > 25% **Highly susceptible**

(B) Against fungus

0 = No wilting, no reduction in dry shoot weight. **Immune**

1 = 1-5% plant body showing wilting, reduction in dry shoot weight 1-5% **Resistant**

2 = 6-15% plant body showing wilting, reduction in dry shoot weight 5.01-10% **Moderately resistant**

3 = 16-25% plant body showing wilting, reduction in dry shoot weight 10.01-15% **Tolerant**

4 = 25-50% plant body showing wilting, reduction in dry shoot weight 15.01-25% **Susceptible**

5 = More than 50% plant body showing wilting, reduction in dry shoot weight more than 25% **Highly susceptible**

Rating on peroxidase activity

0 = More than 60% increase in peroxidase activity **Immune**

1 = 50.01-60% increase in peroxidase activity **Resistant**

2 = 40.01-50% increase in peroxidase activity **Moderately resistant**

3 = 30.01-40% increase in peroxidase activity **Tolerant**

4 = 15.01-30% increase in peroxidase activity **Susceptible**

5 = 0-15% increase in peroxidase activity **Highly susceptible**

Rating on protein content

0 = No increase in protein content	**Immune**
1 = 0-0.50% increase in protein content	**Resistant**
2 = 0.51-1% increase in protein content	**Moderately resistant**
3 = 1.01-2% increase in protein content	**Tolerant**
4 = 2.01-4% increase in protein content	**Susceptible**
5 = > 4% increase in protein content	**Highly susceptible**

Final rating of resistance and susceptibility of a variety was done on the basis of two similar results of atleast two parameters.

Nematode population

For extraction of nematodes from the soil, 250 gm sub-sample of well mixed soil from each treatment was processed by Cobb's sieving and decanting technique followed by Baermann funnel. The nematode suspensions were collected after 24 hrs. and number of nematodes were counted in the counting dish taking three replicates of 2 ml suspension from each sample. Mean of three such countings was obtained and population of nematodes per kg soil was calculated.

For estimation of larvae, eggs and females inside the root, 1 gm root sample was taken from homogenous mixture and macerated for 45 seconds in a blender. Counting was done from suspension thus obtained.

The data obtained were analysed statistically and significance calculated at P = .05 and P = .01 level.

RESULTS

1. Determination of economic threshold levels of test pathogens

In order to determine the threshold levels of Meloidogyne incognita and Macrophomina phaseolina on Cicer arietinum L., the pathogenicity tests were conducted using 500, 1000, 2000, 4000, and 8000 second stage juveniles of the former and 0.25, 0.50, 1.00, 2.00 and 4.00 gm fungal culture of the latter per kg soil. Buffer soluble proteins and peroxidase activity of similarly treated plants were also estimated.

Data presented in table - 1, Fig. 1 showed that plant growth (based on dry shoot weight) progressively decreased with the corresponding increase in the inoculum level of each pathogen. However, statistically significant reductions in growth parameters over control were found only when 2000 or more second stage juveniles of M. incognita or 1 gm or more M. phaseolina per kg soil were inoculated (Appendix - I). Maximum growth reduction was observed at the highest inoculum level of either pathogen. Increase in rotting and wilting due to M. phaseolina was also inoculum dependent (Plate - 1).

Reduction in plant growth (based on dry shoot weight) was directly dependent on the inoculum level of test pathogens (Table - 1, Fig. 1).

TABLE - 1

Effect of different inoculum levels of test pathogens on dry shoot weight, nodulation, disease development and nematode multiplication.

Treatments	Percentage reduction in dry shoot wt.	Percentage reduction in nodulation	Nematode Multiplication	Root Knot Index	Root rot Index
Control	-	-	-	-	-
MI-500	9.68	26.47	38.89	5	-
MI-1000	17.78	35.29	31.30	5	-
MI-2000	25.56	44.12	22.17	5	-
MI-4000	33.02	50.00	13.69	5	-
MI-8000	44.92	61.76	9.14	5	-
MP-0.25	7.94	14.71	-	-	2
MP-0.50	15.71	29.41	-	-	4
MP-1.00	22.54	41.18	-	-	4
MP-2.00	34.60	50.00	-	-	5
MP-4.00	42.86	52.94	-	-	5

MI = Meloidogyne incognita
MP = Macrophomina phaseolina

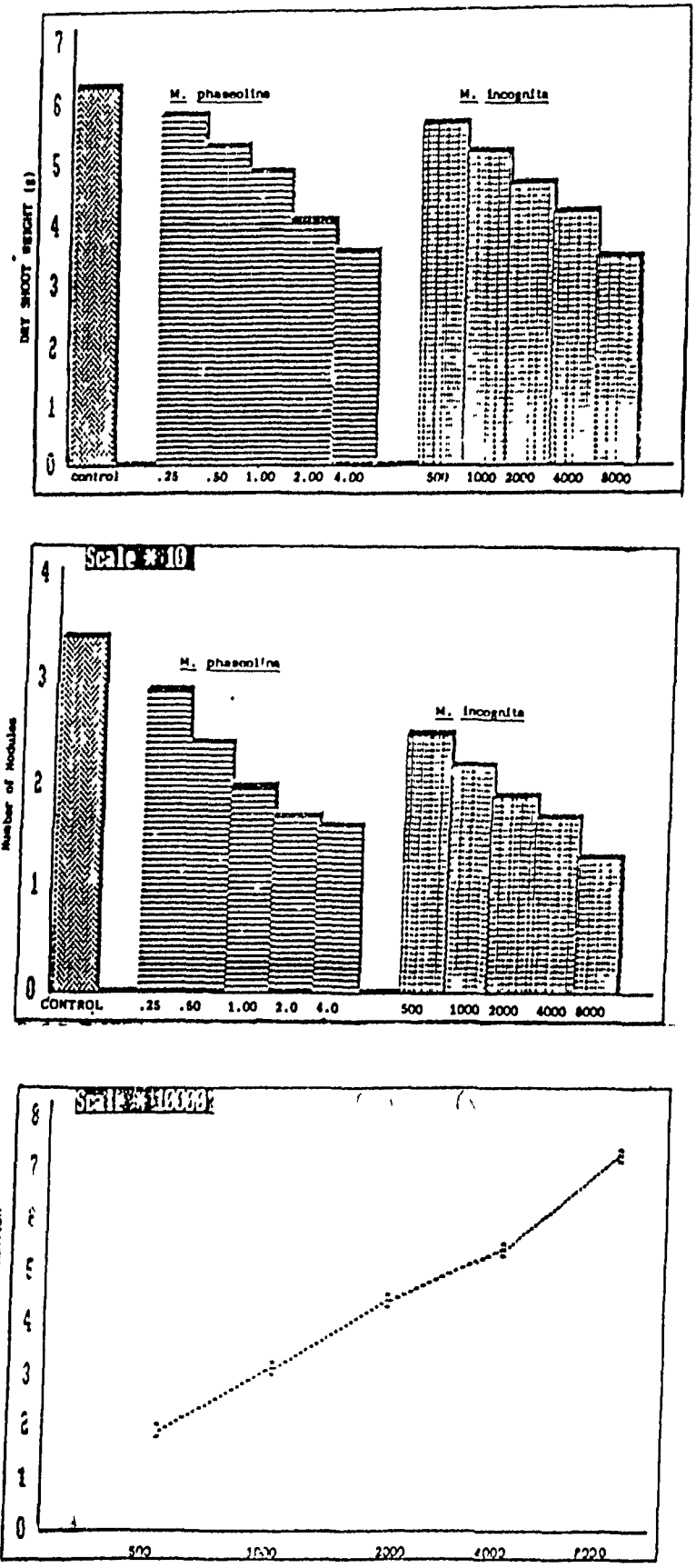


Fig 1. Effect of different inoculum levels of test pathogens on dry shoot weight, nodulation and nematode multiplication.

Plate - 1 Effect of different inoculum levels of test pathogens on plant growth, nodulation and nematode multiplication.

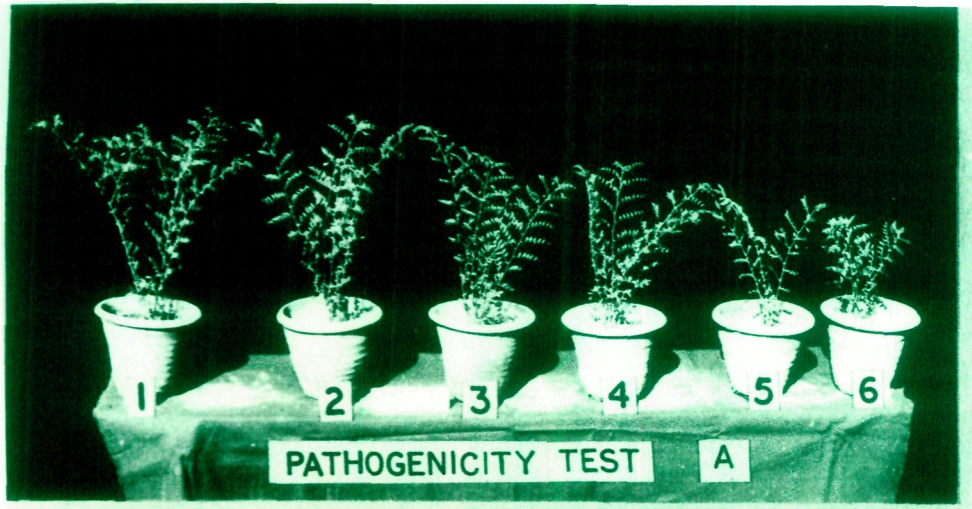
A

1 = Control
2 = *M. incognita* 500
3 = *M. incognita* 1000
4 = *M. incognita* 2000
5 = *M. incognita* 4000
6 = *M. incognita* 8000

B

1 = Control
2 = *M. phaseolina* 0.25
3 = *M. phaseolina* 0.50
4 = *M. phaseolina* 1.00
5 = *M. phaseolina* 2.00
6 = *M. phaseolina* 4.00

PLATE-1


1
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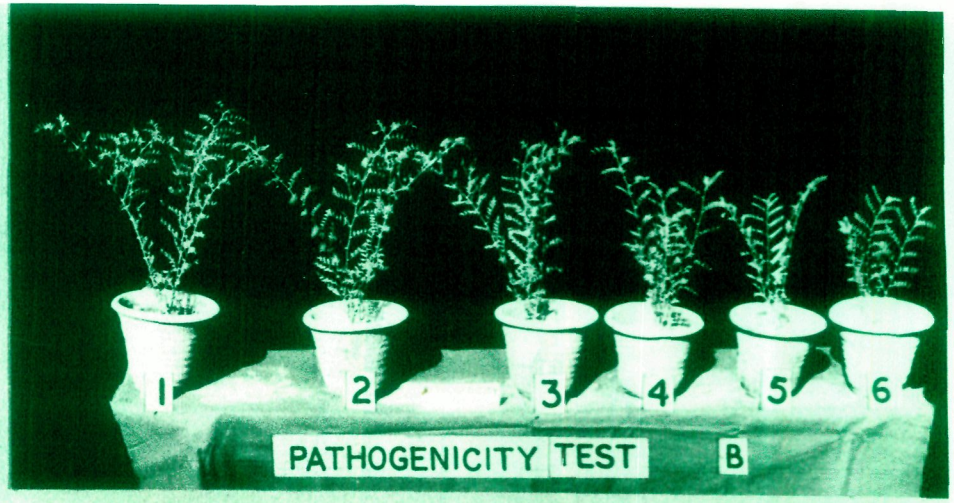
4
5
6
PATHOGENICITY TEST
A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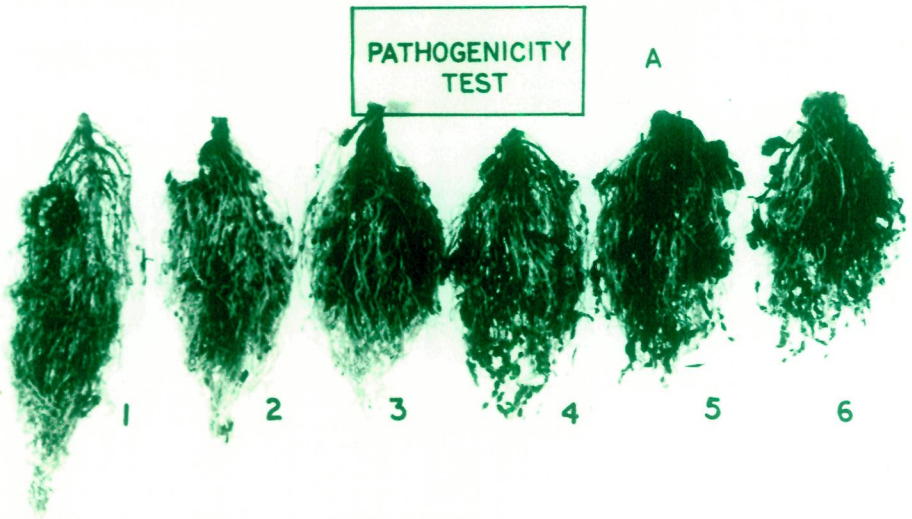
PATHOGENICITY TEST
B


PATHOGENICITY TEST
A
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2
3
4
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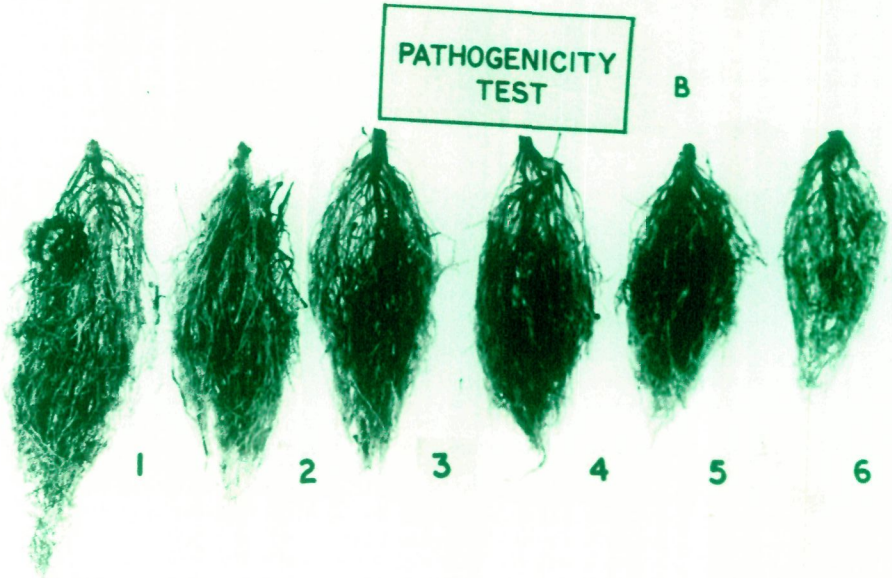
6


PATHOGENICITY TEST
B
1
2
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6

There were considerable decreases in the root nodulation due to the parasitism of both the pathogens but the greater reductions were caused by M. incognita (Table-1, Fig. 1). Nodulation reductions were significant when 500 or more juveniles or 0.50 gm or more of M. phaseolina were inoculated (Appendix - I).

Maximum nematode multiplication (38.89 times) occurred at the lowest (500 juveniles) and minimum (9.14 times) at the highest (8000 juveniles) inoculum of M. incognita (Table - 1, Fig. 1).

Rating of root-knot index was 5 at all the inoculum levels of M. incognita but the root-rot indices were 2, 4, 4, 5 and 5 at 0.25, 0.50, 1.00, 2.00 and 4.00 gm inoculum levels of M. phaseolina respectively (Table - 1).

Economic threshold levels of M. incognita and M. phaseolina were, threrefore, 2000 juveniles of the former and 1 gm culture of the latter. However, M. incognita generally produced more pathogenic effect than M. phaseolina.

Data presented in Appendix - IA, Fig. 1A clearly show that protein contents, both in the shoot and root, were found to increase with an increase in the inoculum level of either pathogen. Increases in the buffer soluble protein of shoot were 1.76, 4.67, 7.66, 8.88 and 10.04% when plants were inoculated with 500, 1000, 2000, 4000 and 8000

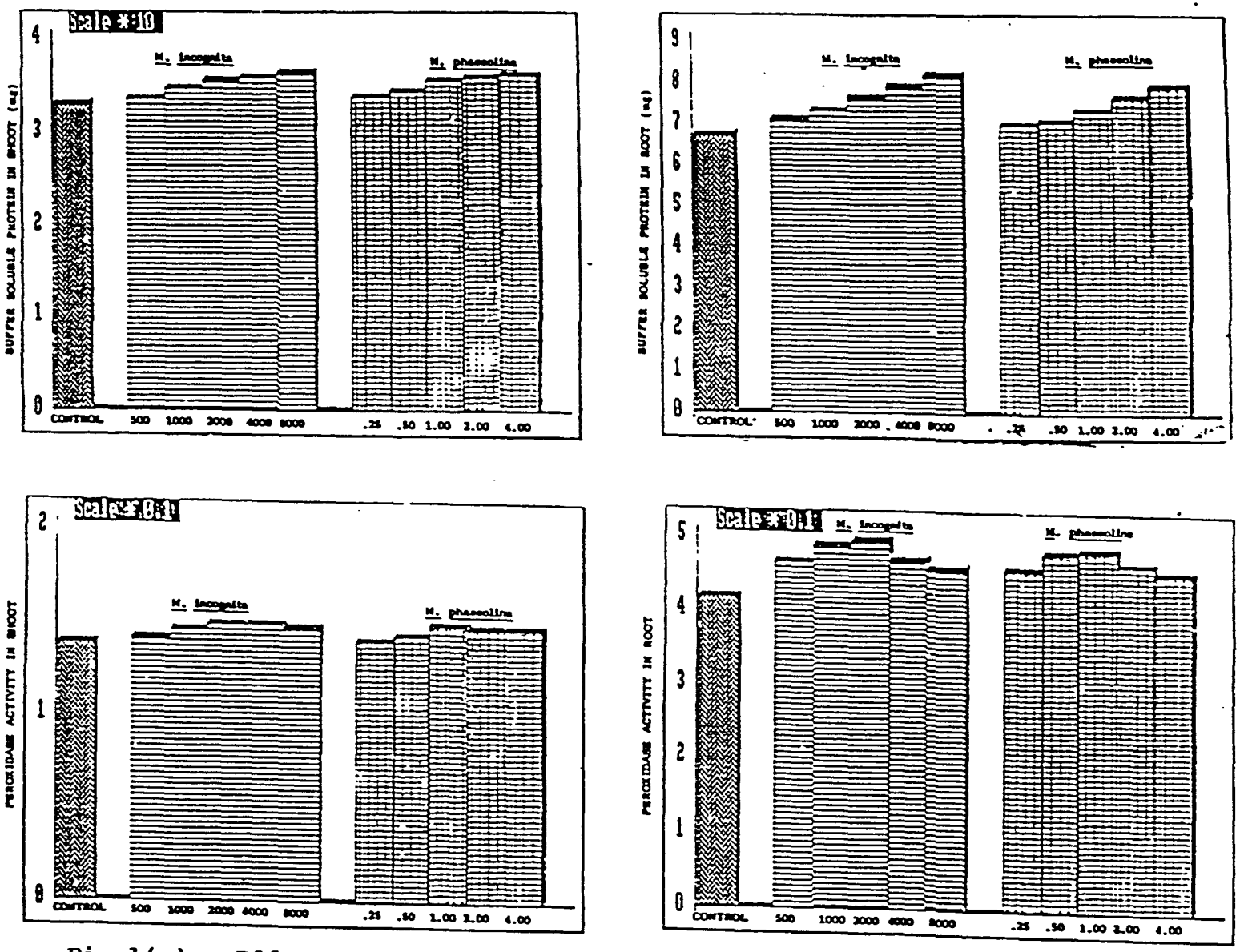


Fig 1(a). Effect of different inoculum levels of test pathogens on buffer soluble protein content and peroxidase activity.

nematodes respectively and 2.13, 3.84, 7.27, 8.31 and 9.37% when inoculated with M. phaseolina @ 0.25, 0.50, 1.00, 2.00 and 4.00 gm respectively. Simiarly, proteins increased in the root by 5.85, 8.77, 13.96, 18.13 and 21.64% when inoculated with 500, 1000, 2000, 4000 and 8000 nematodes and by 3.51, 5.26, 9.36, 13.45 and 17.54% when inoculated with increasing doses of M. phaseolina respectively. The amount of protein was much more in shoot than in the root but the percentage increase in protein due to nematode or fungus infection was high in roots than in shoots. Inoculation of 1000 larvae or 0.50 gm fungus resulted in significant increase in protein in both shoot and root at P=.01.

Specific activity of peroxidase increased due to M. incognita and M. phaseolina inoculation. In shoot the increase over control was 2.17, 5.80, 7.25, 7.25 and 6.52% when inoculated with 500, 1000, 2000, 4000 and 8000 larvae of M. incognita and 1.45, 2.90, 7.97, 6.52 and 6.52% when inoculated with 0.25, 0.50, 1.00, 2.00 and 4.00 gm fungus respectively (Appendix - IB, Fig. 1A). Increases in the peroxidase activity of roots were 11.96, 17.22, 18.66, 13.16 and 10.53% when same five inoculums of M. incognita were used respectively. In case of fungus inoculated plants the increases were 10.29, 15.07, 16.51, 12.20 and 9.57% respectively (Appendix - IB, Fig. 1A). Significant increase in peroxidase activity in shoot was found when 1000 larvae of M. incognita of 1 gm M. phaseolina were inoculated.

However, significant increase in roots were observed when 500 larvae or 0.25 gm fungus were inoculated. Biochemical studies of the plants infected with five different inoculum levels of nematode and fungus separately were conducted with a view to determine whether increase in peroxidase and protein is associated with the increase in the inoculum levels of pathogen. It was observed that protein content increased in both shoot and root with the increase in the inoculum levels of pathogen but peroxidase activity increased when 500-2000 nematodes or 0.25-1.00 gm fungus were inoculated. There was no further increase in peroxidase activity in both shoot and root when more than the above mentioned inoculums were used.

2. Studies on interaction of different inoculum levels of test pathogens

Effect of interaction of different combinations of five variable inoculum levels each of M. incognita (500, 1000, 2000, 4000 and 8000 larvae) and M. phaseolina (0.25, 0.50, 1.00, 2.00 and 4.00 gm) on plant growth, nodulation, disease development and nematode multiplication has been studied.

Various combinations of the variable inoculum levels of test pathogens caused significant decreases in plant growth parameters except when lowest inoculums (500 juveniles plus .25 gm fungus) were used (Appendix - II).

Highest combined inoculums of M. phaseolina and M. incognita (4 gm plus 8000 juveniles) caused servere early rotting and wilting as compared to their lowest combined inoculums (0.25 gm + 500 juveniles). Wilting, however, increased with the plant age. Macrophomina phaseolina, a root-rot fungus, caused sufficient damage to the host root system that hampered the uptake of water resulting in wilting of plants even when sufficient soil moisture was present. Total number of root galls produced by the nematode progressively decreased with the increase in the inoculum level of M. phaseolina (Appendix - II) but the root-rotting increased with the increase in the combined inoculums of M. phaseolina and M. incognita (Plate - 2A&B).

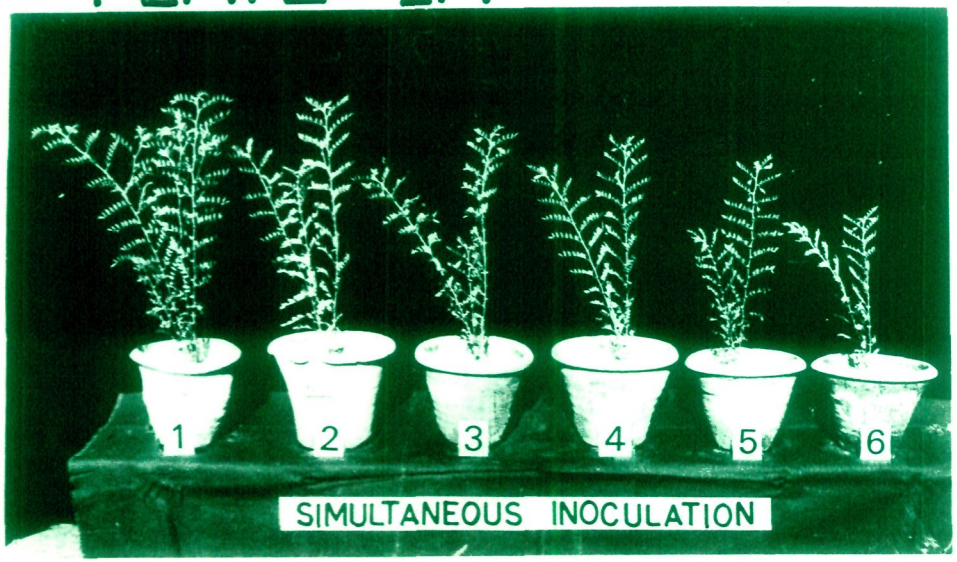
A. Effect on dry shoot weight

Combination of two pathogens caused significant reduction in dry shoot weight except when the lowest inoculums (0.25 gm + 500 juveniles) were used. However, reduction increased more significantly with the increase in the inoculum levels of the two pathogens (Appendix - II, Fig. 2). Simultaneous inoculation with 0.25 gm M. phaseolina in combination with five increasing inoculums of M. incognita caused 15.18 to 61.26% dry shoot weight reductions, 0.50 gm M. phaseolina plus increasing inoculums of M. incognita caused 25.31 to 68.41% reductions, 1.00 gm M. phaseolina plus increasing nematode inoculums caused

Plate - 2A&B Effect of interaction of variable inoculums of test pathogens on plant growth, nodulation and nematode multiplication.

1 = Control
2 = M. phaseolina 0.25 + M. incognita 500
3 = M. phaseolina 0.25 + M. incognita 1000
4 = M. phaseolina 0.25 + M. incognita 2000
5 = M. phaseolina 0.25 + M. incognita 4000
6 = M. phaseolina 0.25 + M. incognita 8000
7 = M. phaseolina 0.50 + M. incognita 500
8 = M. phaseolina 0.50 + M. incognita 1000
9 = M. phaseolina 0.50 + M. incognita 2000
10 = M. phaseolina 0.50 + M. incognita 4000
11 = M. phaseolina 0.50 + M. incognita 8000
12 = M. phaseolina 1.00 + M. incognita 500
13 = M. phaseolina 1.00 + M. incognita 1000
14 = M. phaseolina 1.00 + M. incognita 2000
15 = M. phaseolina 1.00 + M. incognita 4000
16 = M. phaseolina 1.00 + M. incognita 8000
17 = M. phaseolina 2.00 + M. incognita 500
18 = M. phaseolina 2.00 + M. incognita 1000
19 = M. phaseolina 2.00 + M. incognita 2000
20 = M. phaseolina 2.00 + M. incognita 4000
21 = M. phaseolina 2.00 + M. incognita 8000
22 = M. phaseolina 4.00 + M. incognita 500
23 = M. phaseolina 4.00 + M. incognita 1000
24 = M. phaseolina 4.00 + M. incognita 2000
25 = M. phaseolina 4.00 + M. incognita 4000
26 = M. phaseolina 4.00 + M. incognita 8000

PLATE - 2A


1
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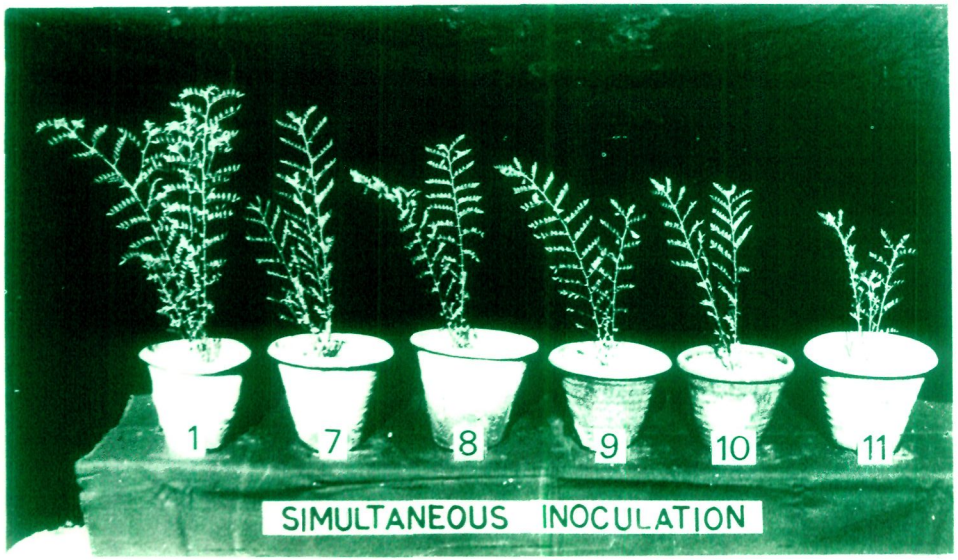
4
5
6
SIMULTANEOUS INOCULATION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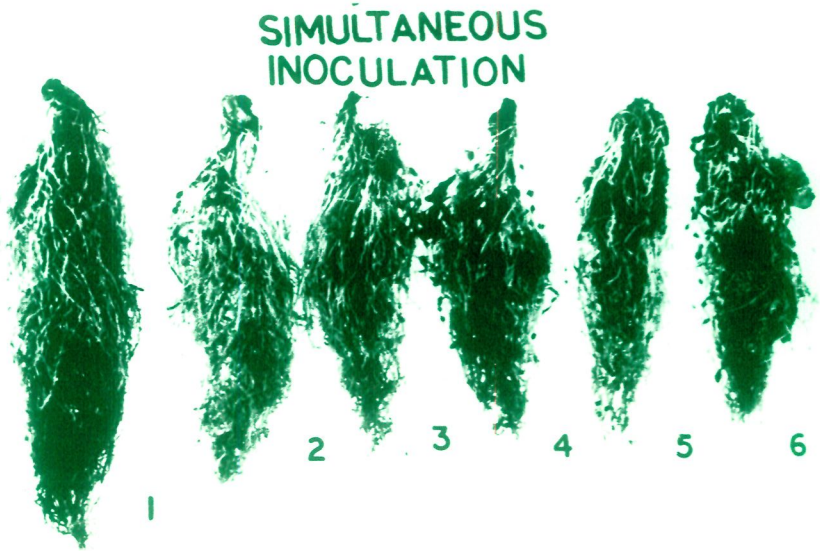
11
SIMULTANEOUS INOCULATION


SIMULTANEOUS
INOCULATION
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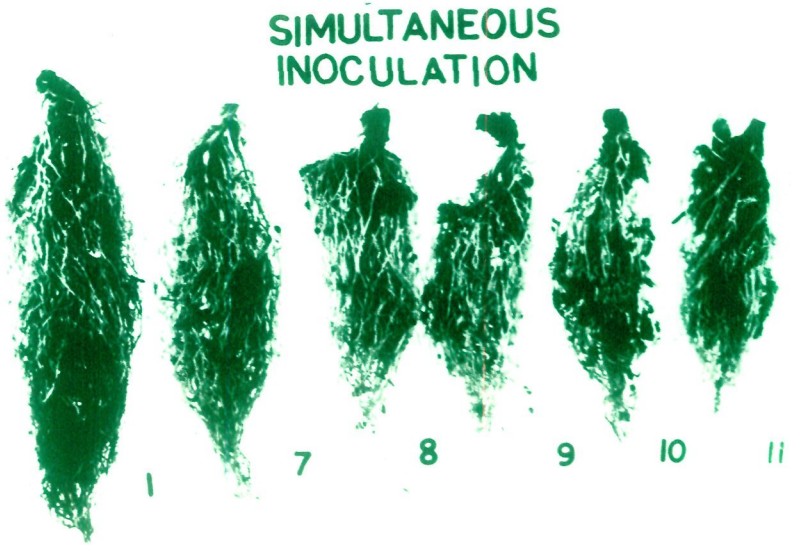
SIMULTANEOUS
INOCULATION
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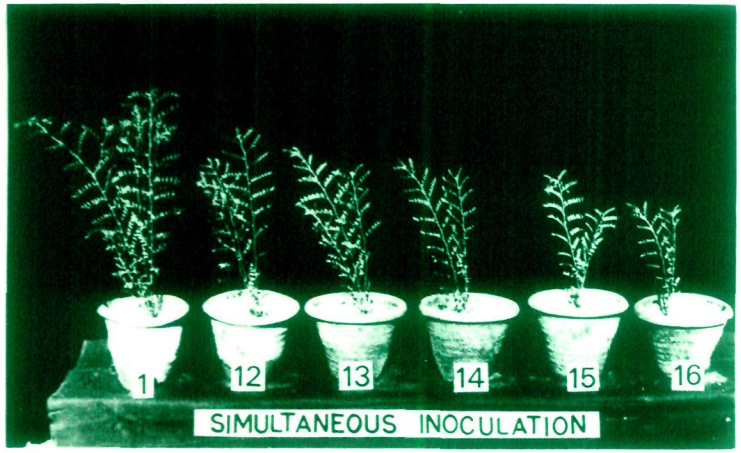
PLATE-213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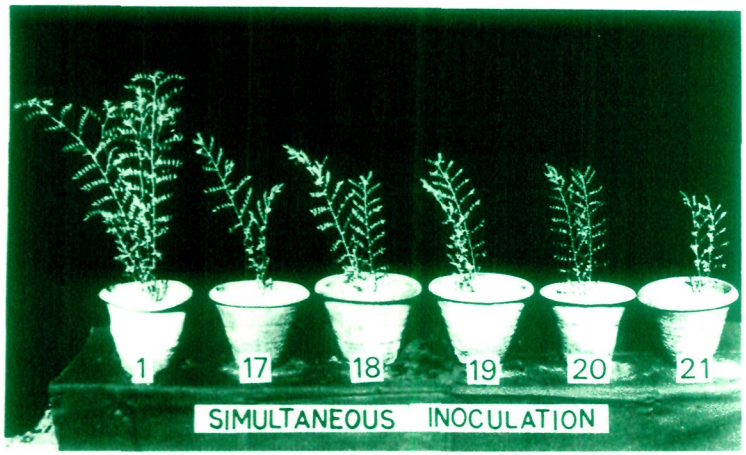
SIMULTANEOUS INOCULATION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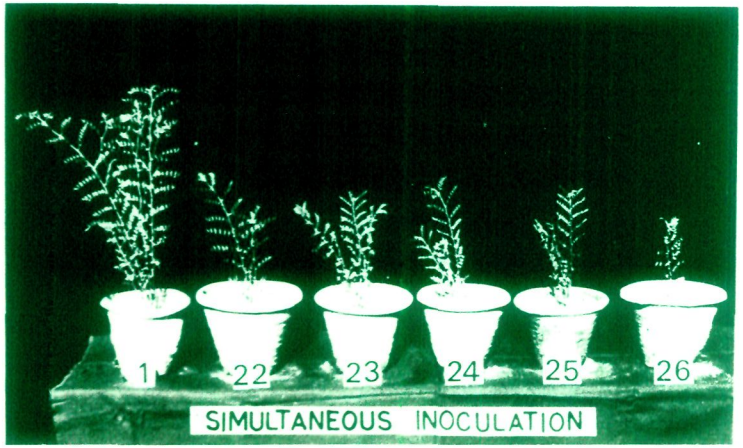
SIMULTANEOUS INOCULATION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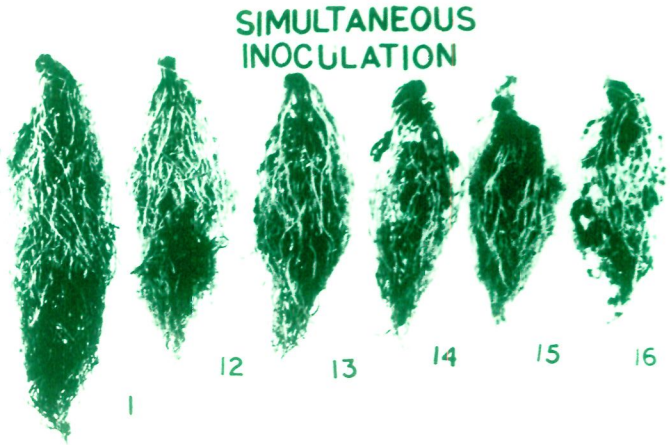
SIMULTANEOUS INOCULATION


SIMULTANEOUS
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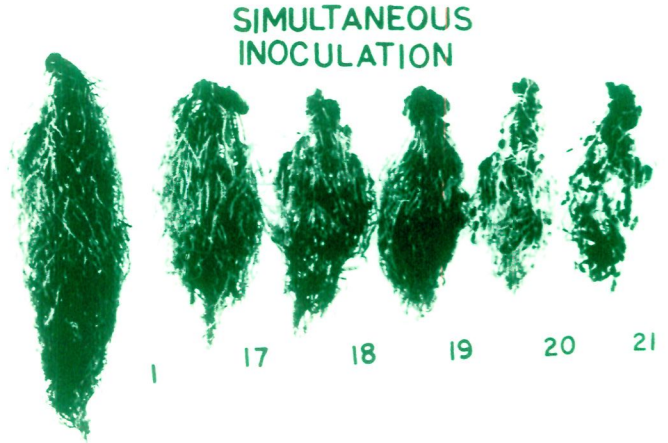
SIMULTANEOUS
INOCULATION
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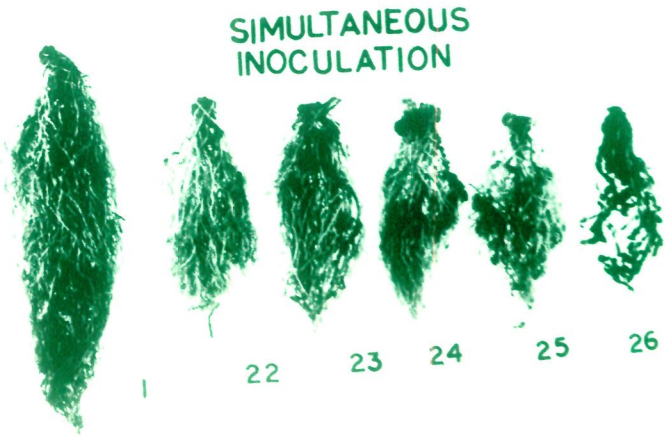

SIMULTANEOUS
INOCULATION
1
22
23
24
25
26

TABLE - 2

Effect of interaction of variable inoculum levels of test pathogens on dry shoot weight, nodulation, disease devolopment and nematode multiplication.

Treatment	Percentage reduction in dry shoot wt.	Percentage reduction in Nodulation	Nematode multiplication	Root knot Index	Root rot Index
1	2	3	4	5	6
C	-	-	-	-	-
MI-500	9.25	24.32	39.10	5	-
MI-1000	17.45	32.43	31.17	5	-
MI-2000	25.48	37.84	22.26	5	-
MI-4000	32.46	48.65	13.57	5	-
MI-8000	44.50	62.16	9.08	5	-
MP-0.25	7.85	16.22	-	-	2
MP-0.50	15.53	24.32	-	-	4
MP-1.00	22.86	40.54	-	-	4
MP-2.00	34.38	48.65	-	-	5
MP-4.00	42.41	54.05	-	-	5
MP-0.25 + MI-500	15.18	35.14	35.18	5	4
MP-0.25 + MI-1000	27.40	45.95	25.43	5	5
MP-0.25 + MI-2000	39.62	51.35	18.31	5	5
MP-0.25 + MI-4000	50.44	59.46	12.51	5	5
MP-0.25 + MI-8000	61.26	70.27	7.45	5	5
MP-0.50 + MI-500	25.31	43.24	29.04	5	5

Contd.....

Table 2 contd.

1	2	3	4	5	6
MP-0.50 + MI-1000	34.38	54.05	21.79	5	5
MP-0.50 + MI-2000	46.95	67.57	16.71	5	5
MP-0.50 + MI-4000	58.46	78.38	10.88	5	5
MP-0.50 + MI-8000	68.41	83.78	6.75	5	5
MP-1.00 + MI-500	33.33	54.05	27.56	5	5
MP-1.00 + MI-1000	47.99	67.57	18.62	5	5
MP-1.00 + MI-2000	57.07	78.38	14.47	5	5
MP-1.00 + MI-4000	66.49	86.49	9.59	5	5
MP-1.00 + MI-8000	70.68	89.19	6.18	5	5
MP-2.00 + MI-500	46.07	64.86	20.42	4	5
MP-2.00 + MI-1000	55.32	78.38	15.62	5	5
MP-2.00 + MI-2000	63.53	86.49	12.76	5	5
MP-2.00 + MI-4000	71.20	94.59	8.49	5	5
MP-2.00 + MI-8000	80.98	100.00	5.48	5	5
MP-4.00 + MI-500	54.28	81.08	16.84	4	5
MP-4.00 + MI-1000	64.40	89.19	12.80	5	5
MP-4.00 + MI-2000	74.00	89.19	10.00	5	5
MP-4.00 + MI-4000	84.1	100.00	6.92	5	5
MP-4.00 + MI-8000	89.18	100.00	4.36	5	5

MI = Meloidogyne incognita
MP = Macrophomina phaseolina

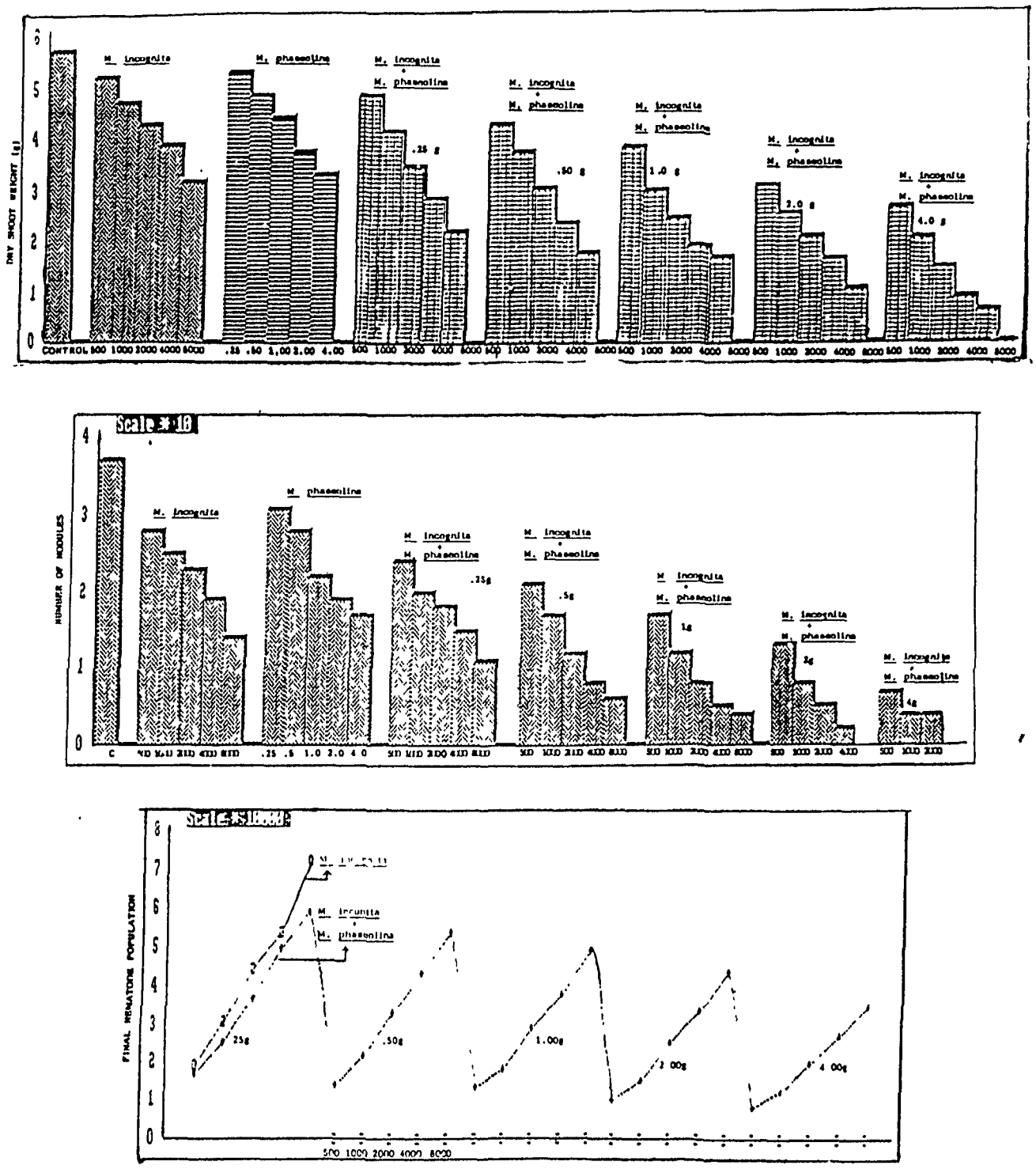


Fig 2. Effect of interaction of variable inoculum levels of test pathogens on dry shoot weight, nodulation and nematode multiplication.

33.33 to 70.68% reductions, 2.00 gm fungus plus increasing nematode inoculums caused 46.07 to 80.98% reductions and 4.00 gm fungus plus increasing nematode inoculums resulted in 54.28 to 89.18% dry shoot weight reductions. In fact all combinations of inoculums of the test pathogens produced synergistic effect on dry shoot weight reductions except when 0.25 gm fungus plus 500 nematodes were used in combination (Table - 2, Appendix - II).

B. Effect on nodulation

Reduction in nodulation was significant over control at P=0.01 level in all treatments except when 0.25 gm fungus was used alone (Appendix - II). In combined inoculations the lowest reduction (35.14%) was found where 0.25 gm M. phaseolina and 500 juveniles of M. incognita were inoculated together (Table - 2, Fig. 2), while nodulation reduction increased to 45.95, 51.35, 59.46 and 70.27% when 0.25 gm fungus was inoculated in combination with 1000, 2000, 4000 and 8000 juveniles of M. incognita respectively. Cent percent reduction in nodulation was observed when 2 gm M. phaseolina plus 8000 nematode or 4 gm M. phaseolina + 4000 nematodes or 4 gm M. phaseolina and 8000 nematodes were inoculated together. Reduction in nodulation in other treatments with combined inoculums ranged between 35.14 to 94.59%

C. Effect on nematode multiplication

When present alone nematode multiplication was density dependent, being highest (39.10 times) at 500 inoculum level and lowest (9.08 times) at 8000 inoculum level. Nematode multiplication consistently decreased in combined inoculations with the increase of fungus inoculum (Table - 2 Fig. 2). Nematode multiplication was 35.18 times when lowest inoculums of both pathogens were used but it decreased to 16.84 times at lowest nematode plus highest fungus inoculum. When highest inoculum of both pathogens were used nematode multiplication was only 4.36 times of the initial inoculum as against 9.08 times when the nematode was present alone.

D. Root-knot and root-rot indices

Root-knot index was 4 when the fungus inoculums were higher (2.00 and 4.00 gm) and the nematode inoculum was lowest (500 nematodes). Increasing nematode inoculums with each set of fungus inoculum caused increased galling (Appendix - II). Therefore, in all other treatments the root-knot index was 5. Root-rot index was 2 when 0.25 gm fungus was inoculated alone, it was 4 in treatments where 0.50 and 1.00 gm fungus was used alone or 0.25 gm fungus plus 500 nematode were inoculated together. In all other treatments root-rot index was 5 (Table - 2).

3. Studies on individual, simultaneous and sequential inoculations of test pathogens

Growth of uninoculated bacterized plants was significantly better than of uninoculated-unbacterized plants (Appendix - III, Plate - 3A&B). When inoculated with either test pathogen or both, the unbacterized plants suffered significantly more damage than bacterized inoculated plants. Inoculation of plants with one or both the pathogens prior to Rhizobium resulted in significantly more reduction in plant growth than caused by simultaneous inoculation of Rhizobium with one or both the pathogens. Inoculation of Rhizobium prior to pathogen/pathogens, on the other hand, resulted in significantly less damage than caused by simultaneous inoculation of Rhizobium and pathogen/pathogens or prior inoculation of pathogen followed by Rhizobium (Plate - 3A&B, Fig. 3). When nematodes were inoculated first followed by fungus and Rhizobium 10 days later, the damage was significantly higher than in all other treatments except when nematode and fungus were inoculated first followed by Rhizobium 10 days later. Prior inoculation of fungus, followed by Rhizobium and nematode inoculation 10 days later, caused significantly less damage than caused by fungus inoculation 10 days later to Rhizobium and nematode. When Rhizobium and fungus were inoculated together followed by nematode the damage was significantly less than in treatment when Rhizobium and nematode were

Plate - 3A&B Effect of individual simultaneous, pre and post inoculation of test pathogens and rhizobium on plant growth, nodulation and nematode multiplication.

1 = Control Bacterized

2 = Control Unbacterized

3 = *M. incognita*

4 = *M. phaseolina*

5 = *M. incognita* + *M. phaseolina*

6 = *M. incognita* + *Rhizobium*

7 = *M. phaseolina* + *Rhizobium*

8 = *M. incognita* + *M. phaseolina* + *Rhizobium*

9 = *M. incognita* ⟶ *Rhizobium*

10 = *M. phaseolina* ⟶ *Rhizobium*

11 = *M. incognita* + *M. phaseolina* ⟶ *Rhizobium*

12 = *Rhizobium* ⟶ *M. incognita*

13 = *Rhizobium* ⟶ *M. phaseolina*

14 = *Rhizobium* ⟶ *M. incognita*

15 = *M. incognita* ⟶ *M. phaseolina* + *Rhiobium*

16 = *M. phaseolina* ⟶ *M. incognita* + *Rhizobium*

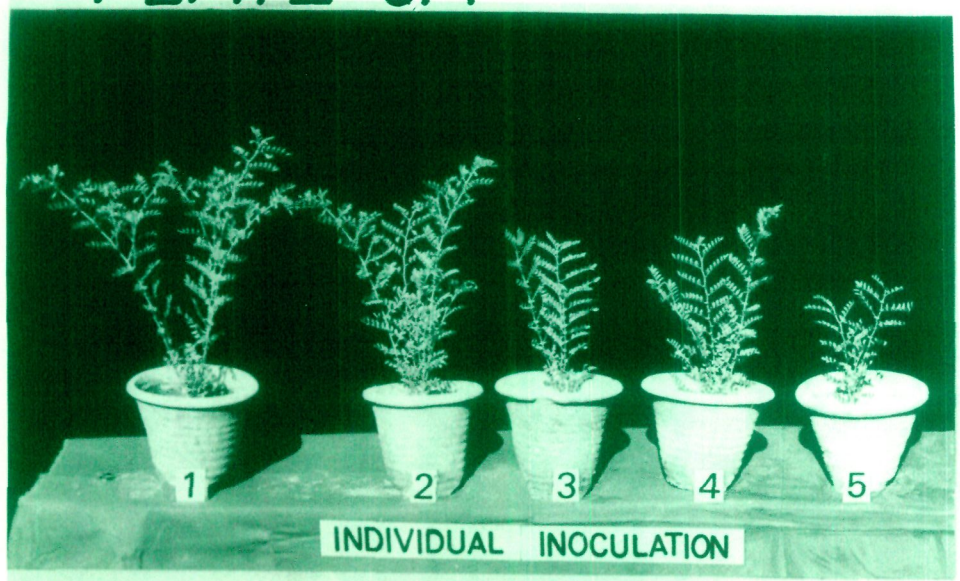
17 = *Rhizobium* + *M. phaseolina* ⟶ *M. incognita*

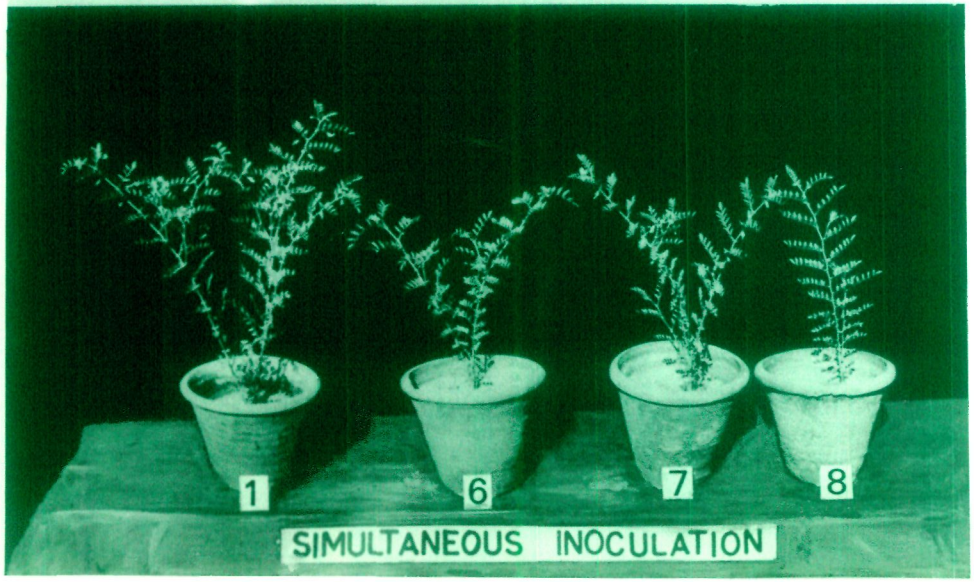
18 = *Rhizobium* + *M. incognita* ⟶ *M. phaseolina*

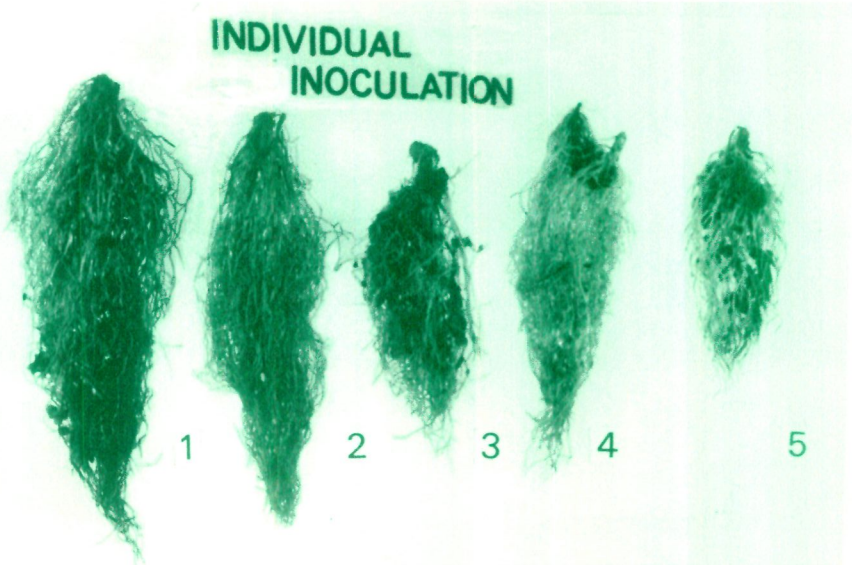
\+ = Simultaneous inoculation

⟶ = Inoculation followed by 10 days later

PLATE-3/A


1
2
3
4
5
INDIVIDUAL INOCULATION


1
6
7
8
SIMULTANEOUS INOCULATION


INDIVIDUAL
INOCULATION
1
2
3
4
5

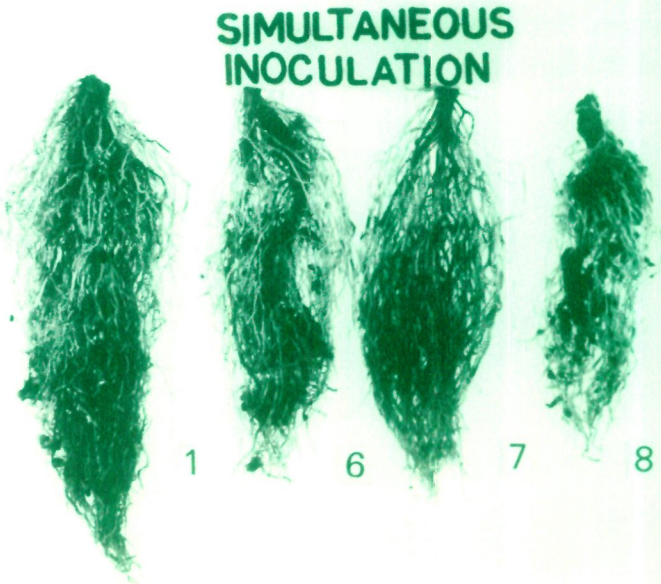
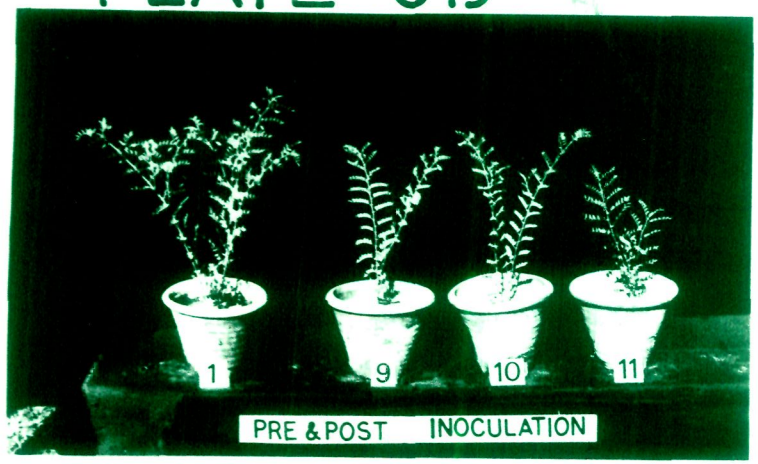
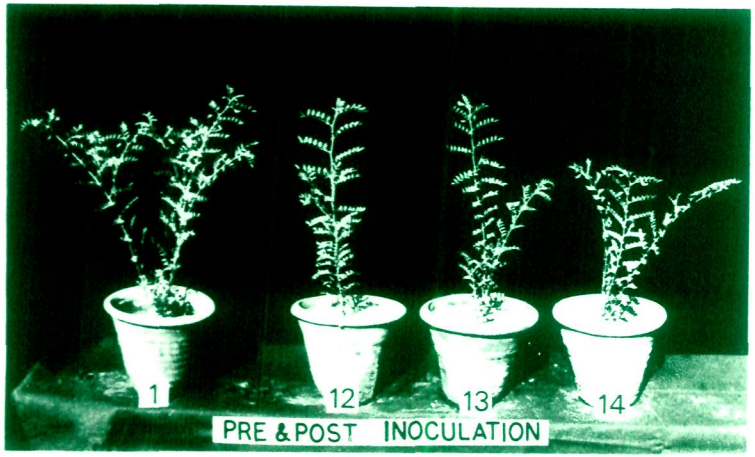
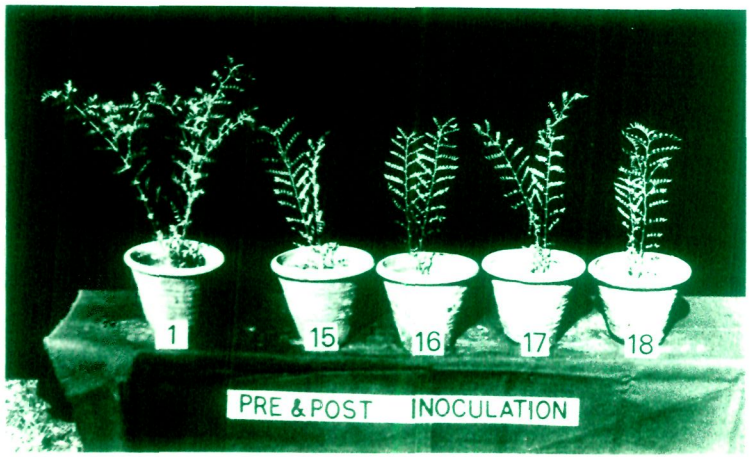
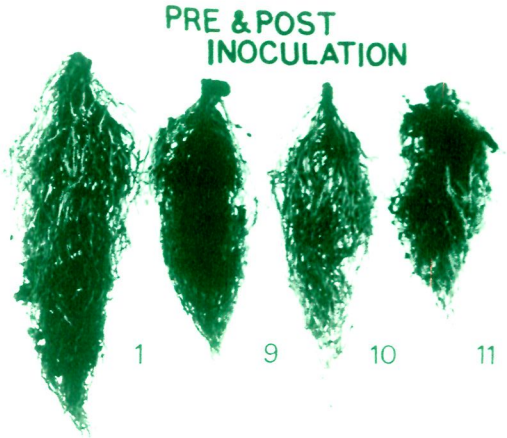

SIMULTANEOUS
INOCULATION
1
6
7
8

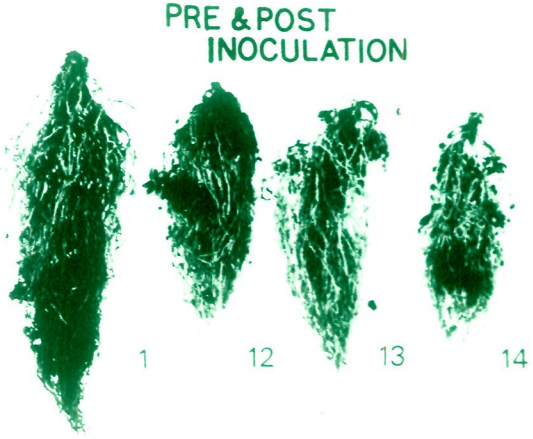
PLATE-31B

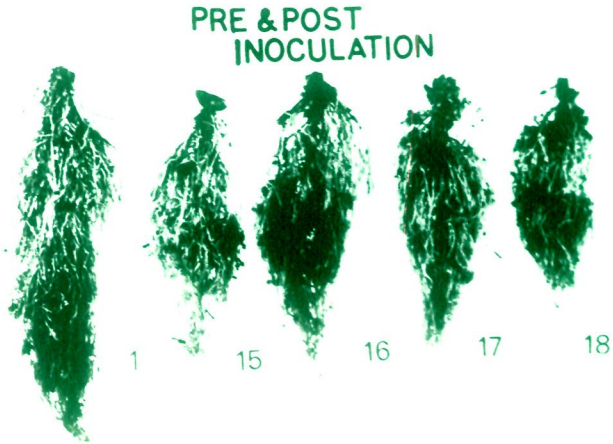

1
9
10
11
PRE & POST INOCULATION


1
12
13
14
PRE & POST INOCULATION


1
15
16
17
18
PRE & POST INOCULATION


PRE & POST
INOCULATION
1
9
10
11


PRE & POST
INOCULATION
1
12
13
14


PRE & POST
INOCULATION
1
15
16
17
18

inoculated first followed by fungus. When the two pathogens were inoculated together the damage was more than the total damage caused by both the pathogens singly (Table - 3).

A. Effect on dry shoot weight

There was 12.13% reduction in plant growth of unbacterized uninoculated plants than bacterized uninoculated plants (Table - 3). When unbacterized plants were inoculated with nematode and fungus separately and with both pathogens together there were 40.73, 36.40 and 79.55% reductions in dry shoot weight whereas the bacterized plants, when inoculated with nematode, fungus separately and with both the pathogens together, suffered 25.65, 22.53 and 50.95% reductions respectively. When Rhizobium inoculation preceded nematode/fungus/nematode plus fungus there were 17.50/14.21/40.55% reductions but when pathogen/pathogens preceded Rhizobium the reductions were 33.80, 31.20 and 68.98% respectively. When nematode was inoculated first and Rhizobium and fungus 10 days later, the reduction in dry shoot weight was 71.40% but it was only 49.57% when fungus was inoculated first in place of nematode in a similar treatment. Prior inoculation of Rhizobium plus fungus followed by nematode inoculations 10 days later caused 47.66% reduction but prior inoculation of Rhizobium plus nematode followed by fungus 10 days later caused 64.47% dry shoot weight reduction.

TABLE - 3

Effect of individual, simultaneous, pre & post inoculations of test pathogens and rhizobium on dry shoot weight, nodulation, desease development and nemotode multiplication.

Treatment	Percentage reduction in dry shoot wt.	Percentage reduction in nodulation	Nemotode multipl-ication	Root knot Index	Root rot index
C Bacterized	-	-	-	-	-
C-Unbactirzed	12.13	100.00	-	-	-
MI "	40.73	100.00	23.27	5	-
MP "	36.40	100.00	-	-	5
MI + MP "	79.55	100.00	18.65	5	5
MI + RH	25.65	28.21	19.98	5	-
MP + RH	22.53	23.08	-	-	4
MI + MP + RH	50.95	51.28	12.52	5	5
MI --> RH	33.80	38.46	21.13	5	-
MP --> RH	31.02	38.46	-	-	5
MI + MP --> RH	68.98	58.97	14.43	5	5
RH --> MI	17.50	12.82	18.55	5	-
RH --> MP	14.21	7.69	-	-	3
RH --> MI + MP	40.55	33.33	11.40	5	5
RH + MP --> MI	47.66	43.59	8.38	5	5
RH + MI --> MP	64.47	41.03	14.17	5	5
MI --> RH + MP	71.40	58.97	14.98	5	5
MP --> RH + MI	49.57	53.85	9.19	5	5

MI = Meloidogyne incognita
MP = Macrophomina phaseolina
RH = Rhizobium

\+ = Simultaneous incoulation
--> = Inoculation followed by 10 days later

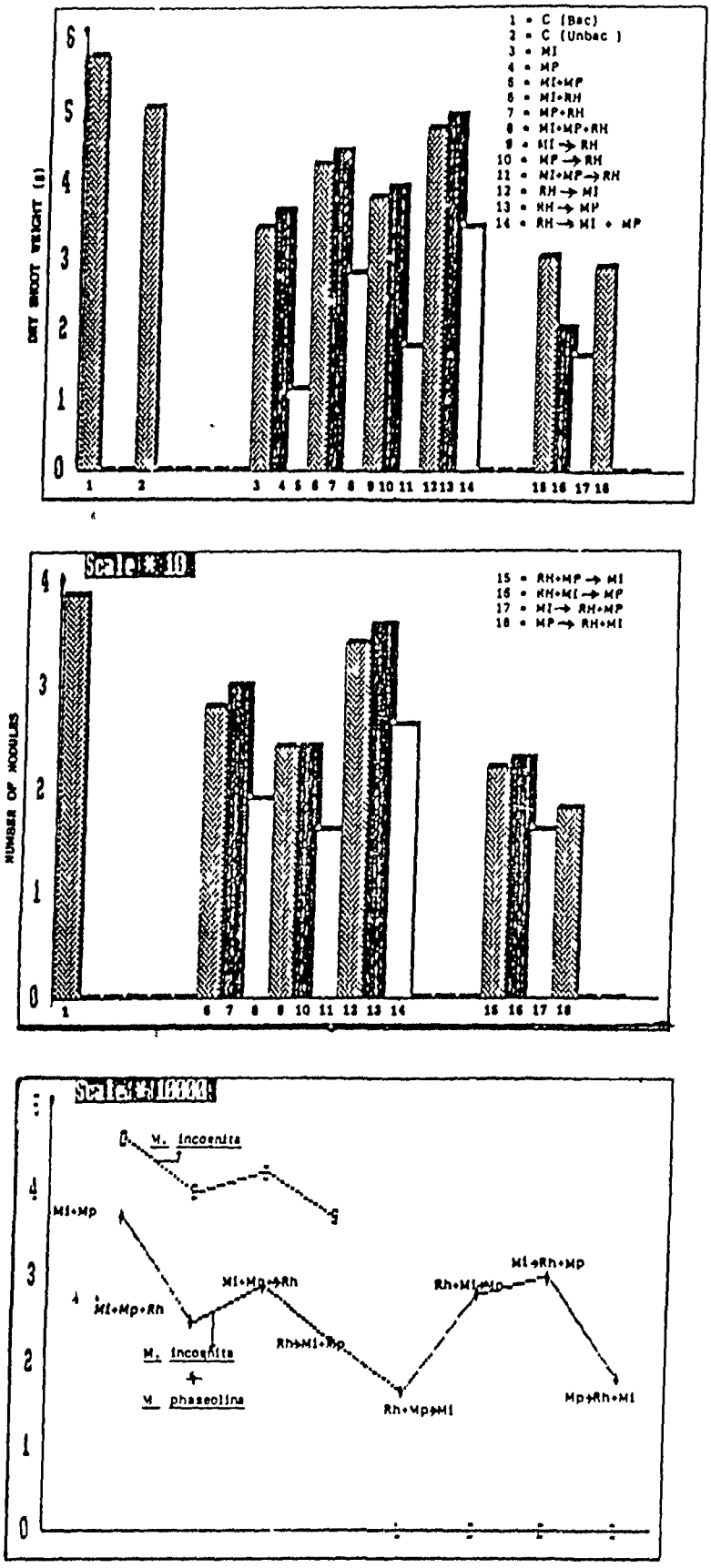


Fig 3. Effect of individual, simultaneous, pre and post incoulation of test pathogens and Rhizobium cn dry shoot weight, noculation and nematode multiplication.

B. Effect on nodulation

There was no nodule formation (100% reduction) in plants without Rhizobium (Table - 3). However, significant reduction in nodulation was observed in all the treatments where Rhizobium plus one or both the pathogens were inoculated when compared with bacterized uninoculated plants (Appendix - III). Plants inoculated with Rhizobium prior to pathogen/pathogens suffered significantly less nodulation reduction (12.82, 7.69 and 33.33%) than plants inoculated with pathogen/pathogens prior to Rhizobium (38.46, 38.46 and 58.97%) or inoculated simultaneously with both (28.21, 23.08 and 51.28%).

C. Effect on nematode multiplication

Nematode multiplication was significantly less in the presence of fungus than when present alone. Presence of Rhizobium also reduced nematode multiplication significantly. In case of unbacterized plants inoculated with nematode alone multiplication was 23.27 times and it reduced to 19.98 times in bacterized nematode inoculated plants. Similarly, in unbacterized plants inoculated with both the pathogens, the multiplication was 18.65 times against 12.52 times in bacterized similarly inoculated plants. When Rhizobium was inoculated prior to nematode or nematode plus fungus the nematode multiplication was much less (18.55 and 11.40 times) than in treatments receiving

nematode or nematode plus fungus inoculations prior to Rhizobium inoculation (21.13 and 14.43 times). Nematode multiplication ranged between 8.38-14.98 times when nematode, fungus and Rhizobium in different combinations of pre and post inoculation were used (Table - 3), highest multiplication occurred when nematode was inoculated first and Rhizobium and fungus 10 days later and lowest when Rhizobium and fungus were inoculated first followed by nematode (Fig. 3).

D. Root-knot and root-rot indices

Root-knot index was 5 in all the treatments where nematode was inoculated but root-rot index was 3 when Rhizobium was inoculated prior to fungus and it was 4 when Rhizobium and fungus were inoculated simultaneously. In all other treatments where M. phaseolina was inoculated, the root-rot index was 5 (Table - 3).

4. Studies on the response of 65 varieties of chickpea against test pathogens

Sixty five chickpea vars. were separately screened for their resistance and susceptibility against Meloidogyne incognita and Macrophomina phaseolina. For resistance/susceptibility rating three parameters were employed namely reduction in dry shoot weight, peroxidase activity and the content of buffer soluble protein in each variety.

A. Reduction in dry shoot weight

Data presented in Appendix - IV clearly showed that none of the 65 vars. were resistant or moderately resistant against either pathogen. Twenty seven vars. were found highly susceptible against M. incognita and 25 against M. phaseolina. Thirty three vars. showed susceptible response against M. phaseolina and 37 against M. incognita while only 1 var. (IC-4944) gave tolerant response against M. incognita and 7 vars. (IC-4919, IC-4923, IC-4928, IC-4938, IC-4942, IC-4950 and IC-4951) against M. phaseolina.

There was only 13.75% dry shoot weight reduction in the nematode tolerent var. (Table - 4). On the other hand, dry shoot weight reductions in susceptible vars. (C-235, BGM-417, IC-4919, IC-4921, IC-4923, IC-4924, IC-4926, IC-4930, IC-4932, IC-4937, IC-4938, IC-4940, IC-4941, IC-4942, IC-4943, IC-4945, IC-4946, IC-4947, IC-4948, IC-4950, IC-4951, IC-4952, IC-4953, IC-4954, IC-4955, IC-4956, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4963, IC-4964, IC-4965, IC-4966, IC-4967 and IC-4968) ranged between 15.38-23.30% (highest in var. IC-4950 and lowest in var. IC-4942) and in highly susceptible var. (Gora Hissar, L-144, Annegiri, Avrodhi, K-850, JG-315, GNG-146, Gaurav, ICC-7002, BG-244, H81-73, BGM-408, P-256, IC-4918, IC-4920, IC-4922, IC-4925, IC-4927, IC-4928, IC-4929, IC-4931, IC-4933, IC-4934, IC-4935, IC-4939, IC-4949 and

IC-4957) it ranged between 25.12-53.64% (highest in var. Gora Hissar and lowest in var. K-4931).

Similarly, 7 fungus tolerant vars. namely IC-4919, IC-4923, IC-4928, IC-4938, IC-4942, IC-4950 and IC-4951 suffered 11.33 to 14.10% reduction in dry shoot weight, highest being in var. IC-4923 and lowest in var. IC-4951 (Table - 4). These reductions in 33 susceptible var. (L-144, Annegiri, JG-315, BG-244, BGM-408, IC-4918, IC-4921, IC-4922, IC-4925, IC-4927, IC-4929, IC-4932, IC-4933, IC-4934, IC-4935, IC-4937, IC-4939, IC-4940, IC-4941, IC-4943, IC-4944, IC-4946, IC-4947, IC-4948, IC-4953, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4964, IC-4965 and IC-4968) ranged between 15.24-25.00% (highest in var. IC-4944 and lowest in var. IC-4918) but in 25 highly susceptible vars. (Gora Hissar, Avrodhi, C-235, BGM-417, K-850, GNG-146, Gaurav, ICC-7002, H81-73, P-256, IC-4920, IC-4924, IC-4926, IC-4930, IC-4931, IC-4945, IC-4949, IC-4952, IC-4954, IC-4955, IC-4956, IC-4957, IC-4963, IC-4966 and IC-4967) the dry shoot weight reductions ranged between 25.22 to 41.52% (highest in var. H81-73 and lowest in var. IC-4924).

B. Effect on nodulation

Both pathogens adversely affected nodulation (Table - 4; Appendix - IV). In the nematode tolerant var. (IC-4944) nodulation reduction was 13.51% but in the

Table - 4

Response of 65 Chick pea varieties against M.incognita and M.phaseolina based on dry shoot weight reduction, nematode multiplication and indices of root knot and root rot.

Variety	Treatment	Percentage reduction in dry shoot weight	Percentage reduction in nodulation	Nematode multiplication	Root Knot Index	Root rot Index	Reaction
1	2	3	4	5	6	7	8
	C	-	-	-	-	-	-
Gora Hissar	MI	53.64	60.00	23.49	5	-	HS
	MP	34.37	40.00	-	-	5	HS
	C	-	-	-	-	-	-
L-144	MI	32.15	40.91	11.20	5	-	HS
	MP	18.02	27.27	-	-	4	S
	C	-	-	-	-	-	-
Annegiri	MI	33.14	41.67	10.30	5	-	HS
	MP	15.42	20.83	-	-	4	S
	C	-	-	-	-	-	-
Avrodhi	MI	36.26	41.67	18.22	5	-	HS
	MP	26.90	41.67	-	-	5	HS
	C	-	-	-	-	-	-
C-235	MI	19.56	36.36	4.09	4	-	S
	MP	27.17	31.82	-	-	5	HS
	C	-	-	-	-	-	-
BGM-417	MI	17.17	38.46	5.01	4	-	S
	MP	26.77	30.77	-	-	5	HS
	C	-	-	-	-	-	-
K-850	MI	25.57	44.12	8.18	5	-	HS
	MP	36.26	35.29	-	-	5	HS
	C	-	-	-	-	-	-
JG-315	MI	31.02	44.44	9.99	5	-	HS
	MP	15.51	27.78	-	-	4	S
	C	-	-	-	-	-	-
GNG-146	MI	37.05	40.00	11.61	5	-	HS
	MP	27.67	33.33	-	-	5	HS

1	2	3	4	5	6	7	8
	C	-	-	-	-	-	-
Gaurav	MI	27.16	50.00	8.02	5	-	HS
	MP	35.18	30.00	-	-	5	HS
	C	-	-	-	-	-	-
ICC-7002	MI	32.97	47.22	10.68	5	-	HS
	MP	25.27	33.33	-	-	5	HS
	C	-	-	-	-	-	-
BG-244	MI	36.61	42.86	14.47	5	-	HS
	MP	22.95	23.81	-	-	4	S
	C	-	-	-	-	-	-
H81-73	MI	33.91	41.43	11.30	5	-	HS
	MP	41.52	35.71	-	-	5	HS
	C	-	-	-	-	-	-
BGM-408	MI	39.14	38.89	16.25	5	-	HS
	MP	19.57	16.67	-	-	4	S
	C	-	-	-	-	-	-
P-256	MI	42.10	48.65	20.95	5	-	HS
	MP	40.79	37.84	-	-	5	HS
	C	-	-	-	-	-	
IC-4918	MI	32.26	34.91	13.78	5	-	HS
	MP	15.24	21.70	-	-	4	S
	C	-	-	-	-	-	-
IC-4919	MI	17.40	15.13	5.25	4	-	S
	MP	13.67	11.18	-	-	3	T
	C	-	-	-	-	-	-
IC-4920	MI	38.03	42.96	15.41	5	-	HS
	MP	28.41	33.33	-	-	5	HS
	C	-	-	-	-	-	-
IC-4921	MI	16.35	32.71	4.14	4	-	S
	MP	15.66	21.50	-	-	4	S
	C	-	-	-	-	-	-
IC-4922	MI	32.38	38.46	11.19	5	-	HS
	MP	16.95	20.88	-	-	4	S
	C	-	-	-	-	-	-
IC-4923	MI	19.31	28.44	5.70	4	-	S
	MP	14.10	15.60	-	-	3	T

Contd.....

1	2	3	4	5	6	7	8
	C	-	-	-	-	-	-
IC-4924	MI	17.83	25.00	5.61	4	-	S
	MP	25.22	31.25	-	-	5	HS
	C	-	-	-	-	-	-
IC-4925	MI	34.,03	41.75	14.06	5	-	HS
	MP	20.76	19.42	-	-	4	S
	C	-	-	-	-	-	-
IC-4926	MI	16.67	27.08	4.96	4	-	S
	MP	27.53	31.25	-	-	5	HS
	C	-	-	-	-	-	-
IC-4927	MI	25.33	45.87	9.27	5	-	HS
	MP	16.01	20.18	-	-	4	S
	C	-	-	-	-	-	-
IC-4928	MI	25.81	45.35	9.23	5	-	HS
	MP	12.91	12.79	-	-	3	T
	C	-	-	-	-	-	-
IC-4929	MI	25.53	47.54	8.46	5	-	HS
	MP	16.67	22.95	-	-	4	S
	C	-	-	-	-	-	-
IC-4930	MI	20.20	28.57	6.46	4	-	S
	MP	34.37	37.14	-	-	5	HS
	C	-	-	-	-	-	-
IC-4931	MI	25.12	41.30	11.01	5	-	HS
	MP	32.51	31.52	-	-	5	HS
	C	-	-	-	-	-	-
IC-4932	MI	16.03	32.00	4.71	4	-	S
	MP	22.16	26.00	-	-	4	S
	C	-	-	-	-	-	-
IC-4933	MI	38.74	45.61	17.20	5	-	HS
	MP	17.80	17.54	-	-	4	S
	C	-	-	-	-	-	-
IC-4934	MI	26.74	47.95	9.67	5	-	HS
	MP	16.39	16.44	-	-	4	S
	C	-	-	-	-	-	-
IC-4935	MI	35.51	46.15	15.96	5	-	HS
	MP	21.42	32.05	-	-	4	S

1	2	3	4	5	6	7	8
	C	-	-	-	-	-	-
IC-4937	MI	18.45	23.30	4.04	4	-	S
	MP	17.09	18.45	-	-	4	S
	C	-	-	-	-	-	-
IC-4938	MI	18.95	31.74	5.22	4	-	S
	MP	13.72	13.48	-	-	3	T
	C	-	-	-	-	-	-
IC-4939	MI	27.38	51.35	11.96	5	-	HS
	MP	18.45	37.84	-	-	4	S
	C	-	-	-	-	-	-
IC-4940	MI	16.06	23.08	6.20	4	-	S
	MP	18.25	30.77	-	-	4	S
	C	-	-	-	-	-	-
IC-4941	MI	18.03	38.27	5.26	4	-	S
	MP	17.01	27.16	-	-	4	S
	C	-	-	-	-	-	-
IC4942	MI	15.38	38.24	4.51	4	-	S
	MP	13.46	11.76	-	-	3	T
	C	-	-	-	-	-	-
IC4943	MI	21.84	38.10	6.50	4	-	S
	MP	16.72	26.19	-	-	4	S
	C	-	-	-	-	-	-
IC4944	MI	13.75	13.51	3.76	3	-	T
	MP	25.00	21.62	-	-	4	S
	C	-	-	-	-	-	-
IC4945	MI	20.00	29,17	4.86	4	-	S
	MP	26.49	33.33	-	-	5	HS
	C	-	-	-	-	-	-
IC4946	MI	19.13	30.77	4.52	4	-	S
	MP	16.78	26.92	-	-	4	S
	C	-	-	-	-	-	-
IC4947	MI	18.18	28.21	6.56	4	-	S
	MP	16.03	23.08	-	-	4	S
	C	-	-	-	-	-	-
IC4948	MI	18.28	28.57	4.52	4	-	S
	MP	19..35	35.71	-	-	4	S

Contd....

1	2	3	4	5	6	7	8
	C	-	-	-	-	-	-
IC4949	MI	29.41	39.29	8.81	5	-	HS
	MP	28.34	35.71	-	-	5	HS
	C	-	-	-	-	-	-
IC4950	MI	23.30	40.00	6.32	4	-	S
	MP	13.64	10.00	-	-	3	T
	C	-	-	-	-	-	-
IC4951	MI	18.23	31.82	6.76	4	-	S
	MP	11.33	15.91	-	-	3	T
	C	-	-	-	-	-	-
IC4952	MI	17.05	23.40	4.56	4	-	S
	MP	27.27	34.04	-	-	5	HS
	C	-	-	-	-	-	-
IC-4953	MI	17.37	33.33	4.68	4	-	S
	MP	15.49	30.43	-	-	4	S
	C	-	-	-	-	-	-
IC=4954	MI	18.35	38.46	5.31	4	-	S
	MP	25.69	30.77	-	-	5	HS
	C	-	-	-	-	-	-
IC-4955	MI	17.92	32.00	4.87	4	-	S
	MP	28.33	48.00	-	-	5	HS
	C	-	-	-	-	-	-
IC-4956	MI	17.97	25.00	6.88	4	-	S
	MP	29.15	30.00	-	-	5	HS
	C	-	-	-	-	-	-
IC-4957	MI	36.91	43.48	13.44	5	-	HS
	MP	38.59	32.61	-	-	5	HS
	C	-	-	-	-	-	-
IC-4958	MI	18.56	23.53	6.52	4	-	S
	MP	16.49	35.29	-	-	4	S
	C	-	-	-	-	-	-
IC-4959	MI	19.42	27.27	4.62	4	-	S
	MP	15.83	18.18	-	-	4	S
	C	-	-	-	-	-	-
IC-4960	MI	16.94	33.33	6.49	4	-	S
	MP	15.30	25.93	-	-	4	S

1	2	3	4	5	6	7	8
	C	-	-	-	-	-	-
IC-4961	MI	18.82	39.13	4.93	4	-	S
	MP	17.20	21.74	-	-	4	S
	C	-	-	-	-	-	-
IC-4962	MI	19.54	37.50	5,94	4	-	S
	MP	22.99	21.88	-	-	4	S
	C	-	-	-	-	-	-
IC-4963	MI	18.28	40.91	5.63	4	-	S
	MP	26.88	36.36	-	-	5	HS
	C	-	-	-	-	-	-
IC-4964	MI	17.37	35.71	5.97	4	-	S
	MP	19.16	32.14	-	-	4	S
	C	-	-	-	-	-	-
IC-4965	MI	16.09	30.43	6.75	4	-	S
	MP	17.82	26.09	-	-	4	S
	C	-	-	-	-	-	-
IC4966	MI	17.39	29.73	4.34	4	-	S
	MP	26.09	37.84	-	-	5	HS
	C	-	-	-	-	-	-
IC-4967	MI	23.08	40.63	6.93	4	-	S
	MP	29.41	37.50	-	-	5	HS
	C	-	-	-	-	-	-
IC-4968	MI	16.59	34.78	5.78	4	-	S
	MP	18.01	26.09	-	-	4	S

C = Control MP = Macrophomina phaseolina

MI = Meloidogyne incognita

susceptible vars. it ranged between 15.13 to 40.91% (highest in var. IC-4963 and lowest in var. IC-4919). Similarly, in the highly susceptible vars. nodulation reduction ranged between 34.91 to 60.00% (highest in var. Gora Hissar and lowest in var. IC-4918).

Varieties tolerant against fungus suffered 10.00 to 15.91% nodulation reduction (highest in var. IC-4951 and lowest in var. IC-4950) while in susceptible vars. these reductions ranged between 16.44 to 37.84% (Table - 4), highest being in var. IC-4939 and lowest in var. IC-4934. On the other hand, reduction in nodulation in highly susceptible vars. ranged between 30.00 to 48.00% (highest in var. IC-4955 and lowest in vars. Gaurav and IC-4956).

C. Nematode multiplication

Nematode multiplication on nematode tolerant var. (IC-4944) was 3.76 times. Similarly, on susceptible vars. it was 4.04 to 6.93 times (highest in var. IC-4967 and lowest in var. IC-4937). Nematode multiplication on the highly susceptible vars. was as high as 23.49 times (var. Gora Hissar) and as low as 8.02 times (var. Gaurav).

D. Root-knot and root-rot indices

Root-knot indices were 3, 4 and 5 in the tolerant, susceptible and highly susceptible vars. respectively and the same was true for root-rot indices (Table - 4).

In general, M. incognita showed more pathogenic effect than M. phaseolina as the average dry shoot weight reduction and nodulation suppression caused by the former were 24.38 and 36.58% respectively against 22.19% and 27.41% caused by the latter.

4.1. Rating of varietial resistance based on peroxidase activity

Only one var. each was rated tolerant against M. incognita (IC-4953) and M. phaseolina (IC-4928) out of 65 vars. tested. Twenty six vars. were found susceptible against M. incognita and 37 against M. phaseolina while 27 were rated highly susceptible against M. phaseolina and 38 against M. incognita (Table - 4A).

Nematode tolerant var. (IC-4953) showed 34.44% increase over the control in its peroxidase activity (Table - 4A) whereas the 26 susceptible vars. (C-235, IC-4919, IC-4921, IC-4923, IC-4924, IC-4926, IC-4932, IC-4937, IC-4938, IC-4941, IC-4942, IC-4944, IC-4945, IC-4948, IC-4951, IC-4952, IC-4955, IC-4956, IC-4958, IC-4960, IC-4961, IC-4962, IC-4963, IC-4964, IC-4965 and IC-4968) showed an increase of 15.12 to 26.69% (highest in var. IC-4937 and lowest in var. IC-4958). Percentage increase in 38 highly susceptible vars. (Gora Hissar, L-144, Annegiri, Avrodhi, BGM-417, K-850, JG-315, GNG-146, Gaurav, ICC-7002, BG-244, H81-73, BGM-408, P-256, IC-4918, IC-4920,

IC-4922, IC-4925, IC-4927, IC-4928, IC-4929, IC-4930, IC-4931, IC-4933, IC-4934, IC-4935, IC-4939, IC-4940, IC-4943, IC-4946, IC-4947, IC-4949, IC-4950, IC-4954, IC-4957, IC-4959, IC-4966 and IC-4967) ranged between 00.00-14.56% (highest in var. IC-4929 and lowest in vars. IC-4922 and IC-4957).

The fungus tolerant var. (IC-4928) showed an increase of 31.61% in its peroxidase activity whereas the 37 susceptible vars. (L-144, Annegiri, JG-315, ICC-7002, BG-244, BGM-408, IC-4918, IC-4919, IC-4921, IC-4922, IC-4923, IC-4924, IC-4925, IC-4927, IC-4929, IC-4933, IC-4934, IC-4937, IC-4938, IC-4939, IC-4940, IC-4941, IC-4942, IC-4943, IC-4948, IC-4949, IC-4950, IC-4951, IC4953, IC-4958, IC-4959, IC-4960, IC-4961, IC-4964, IC-4965, IC-4967 and IC-4968) showed an increase of 15.33-28.03% (highest in var. JG-315 and lowest in var. ICC-7002). Similarly, percentage increase in the highly susceptible vars. (Gora Hissar, Avrodhi, C-235, BGM-417, K-850, GNG-146, Gaurav, H81-73, P-256, IC-4920, IC-4926, IC-4930, IC-4931, IC-4932, IC-4935, IC-4944, IC-4945, IC-4946, IC-4947, IC-4952, IC-4954, IC-4955, IC-4956, IC-4957, IC-4962, IC-4963 and IC-4966) ranged between 1.96-14.50% (highest in var. GNG-146 and lowest in var. IC-4931).

TABLE - 4 A

Response of 65 chick pea varieties against *M. incognita* and *M. phaseolina* based on peroxidase activity & protien content

Variety	Treatment	Peroxidase activity per mg. Protien per minute			Protein (Buffer Soluble)		
		-	% increase	Reaction	-	% increase	Reaction
1	2	3	4	5	6	7	8
	C	0.135	-	-	42.237	-	-
Gora Hissar	MI	0.142	5.19	HS	45.310	7.28	HS
	MP	0.139	2.96	HS	45.310	7.28	HS
P=0.05		0.007			0.145		
P=0.01		0.012			0.240		
	C	0.137	-	-	35.637	-	-
L-144	MI	0.145	5.84	HS	37.793	6.05	HS
	MP	0.175	27.74	S	36.570	2.61	S
P=0.05		0.008			0.202		
P=0.01		0.013			0.335		
	C	0.138		-	41.307	-	-
Annegiri	MI	0.142	2.90	HS	44.293	7.23	HS
	MP	0.170	23.19	S	42.247	2.28	S
P=0.05		0.004			0.105		
P=0.01		0.009			0.173		
	C	0.180	-	-	43.240	-	-
Avrodhi	MI	0.182	1.11	HS	45.493	5.21	HS
	MP	0.205	13.89	HS	44.493	2.90	S
P=0.05		0.011			0.167		
P=0.01		0.018			0.277		
	C	0.248	-	-	35.603	-	-
C-235	MI	0.290	16.94	S	36.327	2.03	S
	MP	0.273	10.08	HS	37.247	4.62	HS
P=0.05		0.012			0.607		
P=0.01		0.020			1.006		

1	2	3	4	5	6	7	8
	C	0.258			36.347	-	-
BGM-417	MI	0.293	13.57	HS	37.097	2.06	S
	MP	0.280	8.53	HS	37.693	3.70	S
P=0.05		0.004			0.168		
P=0.01		0.006			0.279		
	C	0.216			34.977	-	-
K-850	MI	0.237	9.72	HS	36.613	4.68	HS
	MP	0.222	2.78	HS	37.320	6.70	HS
P=0.05		0.005			0.153		
P=0.01		0.009			0.254		
	C	0.132			43.267	-	-
JG-315	MI	0.139	5.30	HS	45.437	5.01	HS
	MP	0.169	28.03	S	43.300	0.08	R
P=0.05		0.011			0.925		
P=0.01		0.018			1.534		
	C	0.200			37.820	-	-
GNG-146	MI	0.201	00.50	HS	39.443	4.29	HS
	MP	0.229	14.50	HS	38.680	2.27	S
P=0.05		0.010			0.144		
P=0.01		0.017			0.238		
	C	0.228			36.353	-	-
Gaurav	MI	0.254	11.40	HS	37.267	2.51	S
	MP	0.235	2.63	HS	38.743	6.57	HS
P=0.05		0.008			0.815		
P=0.01		0.014			1.352		
	C	0.137			38.627	-	-
ICC-7002	MI	0.147	7.30	HS	40.313	4.36	HS
	MP	0.158	15.33	S	40.247	4.19	HS
P=0.05		0.031			0.712		
P=0.01		0.052			1.181		

1	2	3	4	5	6	7	8
	C	0.126			40.307	-	-
BG-244	MI	0.132	4.76	HS	42.210	4.72	HS
	MP	0.154	22.22	←S	42.307	4.96	HS
P=0.05		0.006			0.709		
P=0.01		0.009			1.175		
	C	0.185			35.507	-	-
H 81-73	MI	0.191	3.24	HS	37.090	4.46	HS
	MP	0.198	7.03	HS	37.110	4.51	HS
P=0.05		0.007			0.262		
P=0.01		0.012			0.435		
	C	0.180			38.577	-	-
BGM-408	MI	0.189	5.00	HS	41.263	6.96	HS
	MP	0.226	25.56	S	40.320	4.52	HS
P=0.05		0.007			0.082		
P=0.01		0.012			0.136		
	C	0.140			32.978	-	-
P-256	MI	0.150	6.67	HS	35.123	6.50	HS
	MP	0.149	6.04	HS	34.963	6.02	HS
P=0.05		0.007			0.197		
P=0.01		0.012			0.327		
	C	0.163			37.840	-	-
IC-4918	MI	0.170	4.29	HS	39.913	5.48	HS
	MP	0.199	22.09	S	38.570	1.93	T
P=0.05		0.011			0.767		
P=0.01		0.018			1.271		
	C	0.200			43.303	-	-
IC-4919	MI	0.237	18.50	S	44.350	2.42	S
	MP	0.244	22.00	S	44.120	1.89	T
P=0.05		0.007			1.808		
P=0.01		0.012			2.998		

1	2	3	4	5	6	7	8
	C	0.179			35.470	-	-
IC-4920	MI	0.185	3.35	HS	37.173	4.80	HS
	MP	0.198	10.61	HS	37.073	4.52	HS
P=0.05		0.011			1.236		
P=0.01		0.019			2.050		
	C	0.252			35.470	-	-
IC-4921	MI	0.311	23.41	S	36.200	2.06	S
	MP	0.299	18.65	S	36.287	2.30	S
P=0.05		0.012			0.998		
P=0.01		0.021			1.654		
	C	0.191			37.063	-	-
IC-4922	MI	0.191	-	HS	39.537	6.68	HS
	MP	0.227	18.85	S	38.127	2.87	S
P=0.05		0.009			0.705		
P=0.01		0.015			1.169		
	C	0.231			39.330	-	-
IC-4923	MI	0.269	16.45	S	40.333	2.55	S
	MP	0.277	19.91	S	40.247	2.33	S
P=0.05		0.013			0.252		
P=0.01		0.022			0.418		
	C	0.204			43.110	-	-
IC-4924	MI	0.245	20.10	S	44.470	3.15	S
	MP	0.237	16.18	S	44.667	3/81	S
P=0.05		0.012			1.049		
P=0.01		0.020			1.740		
	C	0.192			34.960	-	-
IC-4925	MI	0.197	2.60	HS	37.447	7.28	HS
	MP	0.223	16.15	S	36.647	4.98	HS
P=0.05		0.004			0.638		
P=0.01		0.007			1.057		

1	2	3	4	5	6	7	8
	C	0.214			39.530	-	-
IC-4926	MI	0.256	19.63	S	40.243	1.80	T
	MP	0.236	10.28	HS	41.070	3.90	S
P=0.05		0.012			0.322		
P=0.01		0.019			0.534		
	C	0.228			36.513	-	-
IC-4927	MI	0.259	13.60	HS	37.807	3.54	S
	MP	0.285	25.00	S	37.067	1.52	T
P=0.05		0.012			0.965		
P=0.01		0.020			1.601		
	C	0.174			42.167	-	-
IC-4928	MI	0.199	14.37	HS	44.050	4.67	HS
	MP	0.229	31.61	T	43.267	2.61	S
P=0.05		0.007			0.467		
P=0.01		0.012			0.775		
	C	0.206			37.747	-	-
IC-4929	MI	0.236	14.56	HS	39.287	4.09	HS
	MP	0.260	26.21	S	39.343	1.59	T
P=0.05		0.010			0.559		
P=0.01		0.016			0.928		
	C	0.207			39.430	-	-
IC-4930	MI	0.226	9.18	HS	41.260	4.64	HS
	MP	0.214	3.38	HS	42.263	7.18	HS
P=0.05		0.011			0.652		
P=0.01		0.019			1.082		
	C	0.204			41.450	-	-
IC-4931	MI	0.230	12.75	HS	43.267	4.38	HS
	MP	0.208	1.96	HS	44.400	7.12	HS
P=0.05		0.009			0.545		
P=0.01		0.014			0.904		

1	2	3	4		5	6	
	C	0.206			35.543	-	-
IC-4932	MI	0.251	21.84	S	36.287	2.09	S
	MP	0.234	13.59	HS	37.040	4.21	HS
P=0.05		0.007			1.023		
P=0.01		0.011			1.697		
	C	0.179			36.157	-	-
IC-4933	MI	0.187	4.47	HS	38.640	6.87	HS
	MP	0.224	25.14	S	37.057	2.49	S
P=0.05		0.005			1.121		
P=0.01		0.009			1.860		
	C	0.195			41.263	-	-
IC-4934	MI	0.217	11.28	HS	43.267	4.86	HS
	MP	0.242	24.10	S	42.193	2.25	S
P=0.05		0.009			1.511		
P=0.01		0.015			2.505		
	C	0.165			36.287	-	-
IC-4935	MI	0.168	1.82	HS	37.747	4.02	HS
	MP	0.185	12.12	HS	37.167	2.43	S
P=0.05		0.004			1.338		
P=0.01		0.007			2.219		
	C	0.236			38.500	-	-
IC-4937	MI	0.299	26.69	S	39.323	2.14	S
	MP	0.291	23.31	S	39.317	2.12	S
P=0.05		0.009			0.462		
P=0.01		0.014			0.767		
	C	0.245			35.090	-	-
IC-4938	MI	0.285	16.33	S	36.123	2.97	S
	MP	0.285	16.33	S	36.287	3.41	S
P=0.05		0.007			0.315		
P=0.01		0.011			0.523		

1	2	3	4	5	6	7	8
	C	0.207			33.856	-	-
IC-4939	MI	0.226	9.18	HS	35.300	4.27	HS
	MP	0.240	15.94	S	35.029	3.46	S
P=0.05		0.015			2.188		
P=0.01		0.024			3.628		
	C	0.163			40.705	-	-
IC-4940	MI	0.185	13.50	HS	41.984	3.14	S
	MP	0.193	18.40	S	41.464	1.86	T
P=0.05		0.013			1.039		
P=0.01		0.022			1.723		
	C	0.194			42.269	-	-
IC-4941	MI	0.224	15.46	S	42.789	1.23	T
	MP	0.227	17.01	S	43.058	1.87	T
P=0.05		0.006			1.114		
P=0.01		0.010			1.848		
	C	0.230			34.737	-	-
IC-4942	MI	0.265	15.22	S	35.100	1.05	T
	MP	0.272	18.26	S	35.290	1.59	T
P=0.05		0.020			1.619		
P=0.01		0.033			2.685		
	C	0.184			40.232	-	-
IC-4943	MI	0.205	11.41	HS	41.716	3.69	S
	MP	0.216	17.39	S	41.210	2.43	S
P=0.05		0.009			0.988		
P=0.01		0.015			1.639		
	C	0.177			38.811	-	-
IC-4944	MI	0.209	18.08	S	39.227	1.07	T
	MP	0.196	10.73	HS	40.232	3.66	S
P=0.05		0.022			1.266		
P=0.01		0.036			2.099		

1	2	3	4	5	6	7	8
	C	0.191			33.170	-	-
IC-4945	MI	0.226	18.32	S	34.070	2.71	S
	MP	0.215	12.57	HS	34.318	3.46	S
P=0.05		0.023			2.030		
P=0.01		0.038			3.367		
	C	0.190			37.927	-	-
IC-4946	MI	0.212	11.58	HS	39.032	2.91	S
	MP	0.215	13.16	HS	38.842	2.41	S
P=0.05		0.012			1.255		
P=0.01		0.019			2.081		
	C	0.175			43.358	-	-
IC-4947	MI	0.189	8.00	HS	44.795	3.31	S
	MP	0.191	9.14	HS	44.,826	3.39	S
P=0.05		0.019			0.971		
P=0.01		0.031			1.610		
	C	0.178			42.300	-	-
IC-4948	MI	0.206	15.73	S	43.626	3.13	S
	MP	0.210	17.98	S	43.673	3.25	S
P=0.05		0.023			1.645		
P=0.01		0.039			2.738		
	C	0.207			35.337	-	-
IC-4949	MI	0.233	12.56	HS	36.592	3.55	S
	MP	0.242	16.91	S	36.592	3.55	S
P=0.05		0.025			2.390		
P=0.01		0.041			3.964		
	C	0.202			38.811	-	-
IC-4950	MI	0.223	10.40	HS	40.453	4.23	HS
	MP	0.238	17.82	S	39.790	2.52	S
P=0.05		0.015			1.202		
P=0.01		0.026			1.994		

1	2	3	4	5	6	7	8
	C	0.135			44.226	-	-
IC-4951	MI	0.157	16.30	S	44.795	1.29	T
	MP	0.160	18.52	S	44.826	1.36	T
P=0.05		0.009			1.066		
P=0.01		0.015			1.767		
	C	0.181			40.705	-	-
IC-4952	MI	0.210	16.02	S	41.716	2.48	S
	MP	0.198	9.39	HS	42.505	4.42	HS
P=0.05		0.013			1.641		
P=0.01		0.021			2.721		
	C	0.180			43.942	-	-
IC-4953	MI	0.242	34.44	T	44.795	1.94	T
	MP	0.217	20.56	S	44.968	2.33	S
P=0.05		0.026			1.261		
P=0.01		0.043			2.091		
	C	0.236			34.169	-	-
IC-4954	MI	0.265	12.29	HS	34.927	2.22	S
	MP	0.263	11.44	HS	35.116	2.77	S
P=0.05		0.022			2.665		
P=0.01		0.036			4.420		
	C	0.175			42.047	-	
IC-4955	MI	0.205	17.14	S	43.058	2.40	S
	MP	0.195	11.14	HS	43.910	4.43	HS
P=0.05		0.011			1.847		
P=0.01		0.019			3.064		
	C	0.209			36.680	-	-
IC-4956	MI	0.250	19.62	S	37.705	2.79	S
	MP	0.227	8.61	HS	38.589	5.20	HS
P=0.05		0.017			1.100		
P=0.01		0.029			1.824		

1	2	3	4	5	6	7	8
	C	0.146			42.961	-	-
IC-4957	MI	0.146	-	HS	45.110	5.00	HS
	MP	0.159	8.90	HS	44.795	4.27	HS
P=0.05		0.007			1.056		
P=0.01		0.012			1.752		
	C	0.172			40.484	-	-
IC-4958	MI	0.198	15.12	S	41.463	2.42	S
	MP	0.204	18.60	S	41.732	3.08	S
P=0.05		0.017			0.545		
P=0.01		0.029			0.904		
	C	0.190			38.589	-	-
IC-4959	MI	0.217	14.21	HS	39.727	2.95	S
	MP	0.222	16.84	S	39.727	2.95	S
P=0.05		0.020			1.904		
P=0.01		0.033			3.158		
	C	0.169			40.737	-	-
IC-4960	MI	0.196	15.78	S	41.731	2.44	S
	MP	0.199	17.75	S	42.016	3.14	S
P=0.05		0.016			1.787		
P=0.01		0.027			2.763		
	C	0.171			41.745	-	-
IC-4961	MI	0.197	15.20	S	42.821	2.58	S
	MP	0.199	16.37	S	42.789	2.51	S
P=0.05		0.014			1.890		
P=0.01		0.023			3,135		
	C	0.195			35.684	-	-
IC-4962	MI	0.226	15.90	S	36.663	2.74	S
	MP	0.219	12.31	HS	37.073	3.90	S
P=0.05		0.011			1.782		
P=0.01		0.019			2.956		

1	2	3	4	5	6	7	8
	C	0.165			40.705	-	-
IC-4963	MI	0.204	23.64	S	41.211	1.24	T
	MP	0.186	12.72	HS	42.237	3.76	S
P=0.05		0.010			0.756		
P=0.01		0.016			1.254		
	C	0.155			43.358	-	-
IC-4964	MI	0.180	16.13	S	44.195	1.93	T
	MP	0.186	20.00	S	43.911	1.28	T
P=0.05		0.012			0.928		
P=0.01		0.020			1.540		
	C	0.189			35.539	-	-
IC-4965	MI	0.223	17.89	S	36.593	2.97	S
	MP	0.231	22.22	S	36.593	2.97	S
P=0.05		0.009			2.028		
P=0.01		0.015			3.364		
	C	0.208			33.457	-	-
IC-4966	MI	0.238	14.42	HS	34.358	2.69	S
	MP	0.226	8.65	HS	34.911	4.35	HS
P=0.05		0.020			1.685		
P=0.01		0.034			2.795		
	C	0.158			39.063	-	-
IC-4967	MI	0.172	8.86	HS	40.200	2.91	S
	MP	0.183	15.82	S	40.453	3.56	S
P=0.05		0.017			1.106		
P=0.01		0.029			1.834		
	C	0.157			40.705	-	-
IC-4968	MI	0.183	16.56	S	41.479	1.90	T
	MP	0.190	21.10	S	41.211	1.24	T
P=0.05		0.013			1.256		
P=0.01		0.022			2.084		

C = Control

MI= Meloidogyne incognita

MP= Macrophomina phaseolina

R = Resistant

MR= Moderately Resistant

= Tolerant

S = Susceptible

4.2. Rating of varietal resistance based on protein content

No var. gave resistant reaction against M. incognita when evaluated on the basis of increase in protein content but one var. (JG-315) was evaluated resistant against M. phaseolina (Table - 4A). Ten vars. were found tolerant against M. phaseolina and 9 against M. incognita whereas 30 were rated susceptible against M. incognita and 35 against M. phaseolina and 26 vars. were highly susceptible against M. incognita but 19 against M. phaseolina.

In the 9 nematode tolerant vars. (IC-4926, IC-4941, IC-4942, IC-4944, IC-4951, IC-4953, IC-4963, IC-4964 and IC-4968) the increase in protein content over control was 1.05-1.94% (highest in var. IC-4953 and lowest in var. IC-4942) while in the 30 susceptible vars. (C-235, BGM-417, Gaurav, IC-4919, IC-4921, IC-4923, IC-4924, IC-4927, IC-4932, IC-4937, IC-4938, IC-4940, IC-4943, IC-4945, IC-4946, IC-4947, IC-4948, IC-4949, IC-4952, IC-4954, IC-4955, IC-4956, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4965, IC-4966 and IC-4967) it ranged between 2.03 to 3.69% (highest in var. IC-4943 and lowest in var. C-235). In the 26 highly-susceptible vars. (Gora Hissar, L-144, Annegiri, Avrodhi, K-850, JG-315, GNG-146, ICC-7002, BG-244, H81-73, BGM-408, P-256, IC-4918, IC-4920, IC-4922, IC-4925, IC-4928, IC-4929, IC-4930, IC-4931, IC-4933, IC-4934, IC-4935, IC-4939, IC-4950 and IC-4957) it was still

higher i.e. 4.02-7.28% (highest in var. IC-4925 and lowest in var. IC-4935).

Variety JG-315, rated resistant against M. phaseolina, showed 0.08% increase in the protein content (Table - 4A). Whereas 10 tolerant vars. (IC-4918, IC-4919, IC-4927, IC-4929, IC-4940, IC-4941, IC-4942, IC-4951, IC-4964 and IC-4968) showed an increase of 1.24 to 1.93% (highest in var. IC-4918 and lowest in var. IC-4968) and 35 susceptible vars. (L-144, Annegiri, Avrodhi, BGM-417, GNG-146, IC-4921, IC-4922, IC-4923, IC-4924, IC-4926, IC-4928, IC-4933, IC-4934, IC-4935, IC-4937, IC-4938, IC-4939, IC-4943, IC-4944, IC-4945, IC-4946, IC-4947, IC-4948, IC-4949, IC-4950, IC-4953, IC-4954, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4963, IC-4965 and IC-4967) showed 2.12. to 3.90% increase in the protein content (highest in vars. IC-4926, IC-4962 and lowest in var. IC-4937). The percentage increase in the protein content in highly susceptible vars. (Gora Hissar, G-235, K-850, Gaurav, ICC-7002, BG-244, H81-73, BGM-408, P-256, IC-4920, IC-4925, IC-4930, IC-4931, IC-4932, IC-4952, IC-4955, IC-4956, IC-4957 and IC-4966) ranged between 4.19-7.28% (highest in var. Gora Hissar and lowest in var. ICC-7002).

4.3. Final rating

Final rating was done on the basis of 2 or 3 similar responses of three parameters used (Table - 4B). Thus,

against M. incognita 2 vars. (IC-4944 and IC-4953) were found tolerant, 34 vars. (C-235, BGM-417, IC-4919, IC-4921, IC-4923, IC-4924, IC-4926, IC-4932, IC-4937, IC-4938, IC-4940, IC-4941, IC-4942, IC-4943, IC-4945, IC-4946, IC-4947, IC-4948, IC-4951, IC-4952, IC-4954, IC-4955, IC-4956, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4963, IC-4964, IC-4965, IC-4966, IC-4967 and IC-4968) gave susceptible reaction and 29 vars. (Gora Hissar, L-144, Annegiri, Avrodhi, K-850, JG-315, GNG-146, Gaurav, ICC-7002, BG-244, H81-73, BGM-408, P-256, IC-4918, IC-4920, IC-4922, IC-4925, IC-4927, IC-4928, IC-4929, IC-4930, IC-4931, IC-4933, IC-4934, IC-4935, IC-4939, IC-4949, IC-4950 and IC-4957) were highly susceptible.

Similarly, against M. phaseolina 4 vars. (IC-4919, IC-4928, IC-4942 and IC-4951) were found tolerant, 38 vars. (L-144, Annegiri, JG-315, BG-244, BGM-408, IC-4918, IC-4921, IC-4922, IC-4923, IC-4924, IC-4925, IC-4927, IC-4929, IC-4933, IC-4934, IC-4935, IC-4937, IC-4938, IC-4939, IC-4940, IC-4941, IC-4943, IC-4944, IC-4946, IC-4947, IC-4948, IC-4949, IC-4950, IC-4953, IC-4958, IC-4959, IC-4960, IC-4961, IC-4962, IC-4964, IC-4965, IC-4967 and IC-4968) were susceptible and 23 vars. (Gora Hissar, Avrodhi, C-235, BGM-417, K-850, GNG-146, Gaurav, ICC-7002, H81-73, P-256, IC-4920, IC-4926, IC-4930, IC-4931, IC-4932, IC-4945, IC-4952, IC-4954, IC-4955, IC-4956, IC-4957, IC-4963 and IC-4966) were highly susceptible (Table - 4B).

TABLE - 4B

Final Response of 65 chickpea varieties based on the three parameters used.

Variety	Treat-ment	Reaction based on % dry wt. root knot and root rot indices	Reaction based on peroxidase activity	Reaction based on protien content	Overall reaction
1	2	3	4	5	6
Gora	MI	HS	HS	HS	HS
Hissar	MP	HS	HS	HS	HS
L-144	MI	HS	HS	HS	HS
	MP	S	S	S	S
Annegiri	MI	HS	HS	HS	HS
	MP	S	S	S	S
Avrodhi	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
C-235	MI	S	S	S	S
	MP	HS	HS	HS	HS
BGM-417	MI	S	HS	S	S
	MP	HS	HS	S	HS
K-850	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
JG-315	MI	HS	HS	HS	HS
	MP	S	S	R	S
GNG-146	MI	HS	HS	HS	HS
	MP	HS	HS	S	HS
Gaurav	MI	HS	HS	S	HS
	MP	HS	HS	HS	HS
ICC-7002	MI	HS	HS	HS	HS
	MP	HS	S	HS	HS
BG-244	MI	HS	HS	HS	HS
	MP	S	S	HS	S

1	2	3	4	5	6
H 81-73	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
BGM-408	MI	HS	HS	HS	HS
	MP	S	S	HS	S
P-256	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
IC-4918	MI	HS	HS	HS	HS
	MP	S	S	T	S
IC-4919	MI	S	S	S	S
	MP	T	S	T	T
IC-4920	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
IC-4921	MI	S	S	S	S
	MP	S	S	S	S
IC-4922	MI	HS	HS	HS	HS
	MP	S	S	S	S
IC-4923	MI	S	S	S	S
	MP	T	S	S	S
IC-4924	MI	S	S	S	S
	MP	HS	S	S	S
IC-4925	MI	HS	HS	HS	HS
	MP	S	S	HS	S
IC-4926	MI	S	S	T	S
	MP	HS	HS	S	HS
IC-4927	MI	HS	HS	S	HS
	MP	S	S	T	S
IC-4928	MI	HS	HS	HS	HS
	MP	T	T	S	T
IC-4929	MI	HS	HS	HS	HS
	MP	S	S	T	S

1	2	3	4	5	6
IC-4930	MI	S	HS	HS	HS
	MP	HS	HS	HS	HS
IC-4931	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
IC-4932	MI	S	S	S	S
	MP	S	HS	HS	HS
IC-4933	MI	HS	HS	HS	HS
	MP	S	S	S	S
IC-4934	MI	HS	HS	HS	HS
	MP	S	S	S	S
IC-4935	MI	HS	HS	S	HS
	MP	S	HS	S	S
IC-4937	MI	S	S	S	S
	MP	S	S	S	S
IC-4938	MI	S	S	S	S
	MP	T	S	S	S
IC-4939	MI	HS	HS	HS	HS
	MP	S	S	S	S
IC-4940	MI	S	HS	S	S
	MP	S	S	T	S
IC-4941	MI	S	S	T	S
	MP	S	S	T	S
IC-4942	MI	S	S	T	S
	MP	T	S	T	T
IC-4943	MI	S	HS	S	S
	MP	S	S	S	S
IC-4944	MI	T	S	T	T
	MP	S	HS	S	S

1	2	3	4	5	6
IC-4945	MI	S	S	S	S
	MP	HS	HS	S	HS
IC-4946	MI	S	HS	S	S
	MP	S	HS	S	S
IC-4947	MI	S	HS	S	S
	MP	S	HS	S	S
IC-4948	MI	S	S	S	S
	MP	S	S	S	S
IC-4949	MI	HS	HS	S	HS
	MP	HS	S	S	S
IC-4950	MI	S	HS	HS	HS
	MP	T	S	S	S
IC-4951	MI	S	S	T	S
	MP	T	S	T	T
IC-4952	MI	S	S	S	S
	MP	HS	HS	HS	HS
IC-4953	MI	S	T	T	T
	MP	S	S	S	S
IC-4954	MI	S	HS	S	S
	MP	HS	HS	S	HS
IC-4955	MI	S	S	S	S
	MP	HS	HS	HS	HS
IC-4956	MI	S	S	S	S
	MP	HS	HS	HS	HS
IC-4957	MI	HS	HS	HS	HS
	MP	HS	HS	HS	HS
IC-4958	MI	S	S	S	S
	MP	S	S	S	S

1	2	3	4	5	6
IC-4959	MI	S	HS	S	S
	MP	S	S	S	S
IC-4960	MI	S	S	S	S
	MP	S	S	S	S
IC-4961	MI	S	S	S	S
	MP	S	S	S	S
IC-4962	MI	S	S	S	S
	MP	S	HS	S	S
IC-4963	MI	S	S	T	S
	MP	HS	HS	S	HS
IC-4964	MI	S	S	T	S
	MP	S	S	T	S
IC-4965	MI	S	S	S	S
	MP	S	S	S	S
IC-4966	MI	S	HS	S	S
	MP	HS	S	HS	HS
IC-4967	MI	S	HS	S	S
	MP	HS	S	S	S
IC-4968	MI	S	S	T	S
	MP	S	S	T	S

MI = Meloidogyne incognita

MP = Macrophomina phaseolina

R = Resistant

MR = Moderatily resistant

T = Toterant

S = Susceptible

HS = Highly susceptible

5. Effect of ascorbic acid and *P. lilacinus* on plant growth, nodulation, disease development and nematode multiplication

Efficacy of ascorbic acid was tested for the control of root-rot disease caused by *M. phaseolina* and the root-knot disease caused either by *M. incognita* alone or in association with *M. phaseolina* and compared with the efficacy of *P. lilacinus*. Both the materials significantly improved growth of infected plants in all the treatments except when *M. phaseolina* infected plants were given foliar spray and 5 ml soil dose of ascorbic acid and 0.5 and 1.0 gm doses of *P. lilacinus*. Application of ascorbic acid improved nodulation significantly of nematode inoculated plants except when foliar spray and 5 ml soil dose were given but the application of *P. lilacinus* improved nodulation in all the treatments against nematode infected plants (Appendix - V). However, against *M. phaseolina* inoculated plants though ascorbic acid treatments caused no significant improvement in nodulation but the high dose of *P. lilacinus* caused significant improvement. All treatments of ascorbic acid and *P. lilacinus*, except foliar spray and 5 ml soil dose of the former and 0.5 gm soil application of the latter, caused significant improvement in nodulation in plants concomitantly inoculated with both the pathogens. All the treatments with ascorbic acid and *P. lilacinus* significantly reduced nematode multiplication whether present singly or with *M. phaseolina* (Appendix - V).

A. Effect on dry shoot weight

Nematode alone caused 26.12% reduction in dry shoot weight over uninoculated control (Table - 5, Fig. 4) but all the treatments of nematode inoculated plants with ascorbic acid (seed treatment, foliar spray and soil application with 5, 10 and 20 ml) and P. lilacinus (0.5, 1.0 and 2.0 gm) caused improvement in plant growth (13.09, 8.59, 7.81, 11.91, 18.75, 9.38, 19.14 and 25.59% respectively). Macrophomina phaseolina, when percent alone, caused 24.96% dry shoot weight reduction but when the fungus inoculated plants were treated with ascorbic acid (seed treatment, 10 and 20 ml soil doses) and P. lilacinus (2.0 gm) there were 8.08, 7.50, 12.88 and 12.88% increases in dry shoot weight respectively. The two pathogens together caused 52.09% reduction but the application of ascorbic acid (seed treatment, foliar spray, 5, 10 and 20 ml soil doses) and P. lilacinus (0.5, 1.0 and 2.0 gm) increased plant growth by 34.04, 28.61, 22.59, 36.45, 47.59, 24.10, 53.01 and 72.29% respectively over inoculated and untreated control.

B. Effect on nodulation

Nematode inoculation resulted in 42.86% reduction in nodulation but the application of ascorbic acid and P. lilacinus increased nodulation by 12.50-62.50% (Table - 5 Fig. 4). Macrophomina phaseolina caused 30.95% reduction in nodulation but ascorbic acid and P. lilacinus treatments

Table-5. Effect of ascorbic acid and *P. lilacinus* on dry shoot weight reduction, nodulation and nematode multiplication

Treatment		1	2	3	4	5	6	7
C		-	-	-	-	-	-	-
MI		26.12	-	42.86	-	-	5	-
MP		24.96	-	30.95	-	-	-	4
MI+MP		52.09	-	71.43	-	-	5	5
Ascobic Acid								
MI	Seed	16.45	13.09	28.57	25.00	54.67	5	-
MP	Treat-	18.90	8.08	23.81	10.34	-	-	4
MI+MP	ment	35.79	34.04	57.14	50.00	43.76	5	5
MI	Foliar	19.77	8.59	35.71	12.50	29.37	5	-
MP	spray	21.36	4.81	30.95	-	-	-	4
MI+MP		38.38	28.61	61.90	33.33	31.17	5	5
Soil doses								
MI		20.35	7.81	33.33	16.67	29.37	5	-
MP	5 ml	22.08	3.85	26.19	6.90	-	-	4
MI+MP		41.27	22.59	59.52	41.67	31.84	5	5
MI		17.32	11.91	26.19	29.17	57.03	5	-
MP	10 ml	19.34	7.50	19.05	17.24	-	-	4
MI+MP		34.63	36.45	54.76	58.33	40.38	5	5
MI		12.27	18.75	16.67	45.83	63.66	5	-
MP	20 ml	15.30	12.88	19.05	17.24	-	-	4
MI+MP		29.29	47.59	47.62	83.33	68.43	4	5
P. lilacinus								
MI		19.19	9.38	26.19	29.17	29.93	5	-
MP	0.5 gm	22.66	3.08	23.81	10.34	-	-	4
MI+MP		40.55	24.10	59.52	41.67	31.65	5	5
MI		11.98	19.14	16.67	45.83	57.01	5	-
MP	1.0 gm	19.77	6.92	19.05	17.24	-	-	4
MI+MP		26.70	53.01	52.38	66.67	56.26	5	5
MI		7.22	25.59	7.14	62.50	75.44	4	-
MP	2.0 gm	15.30	12.88	11.90	27.59	-	-	4
MI+MP		17.46	72.29	45.24	91.67	74.01	4	4

1 - % decrease in DSW over uninoculated control
2 - % increase in DSW over inoculated control
3 - % decrease in nodulation over uninoculated control
4 - % increase in nodulation over inoculated control
5 - % decrease in nematode multiplication
6 - Root-knot index 7 - Root-rot index
MI - *Meloidogyne incognita* MP - *Macrophomina phaseolina*

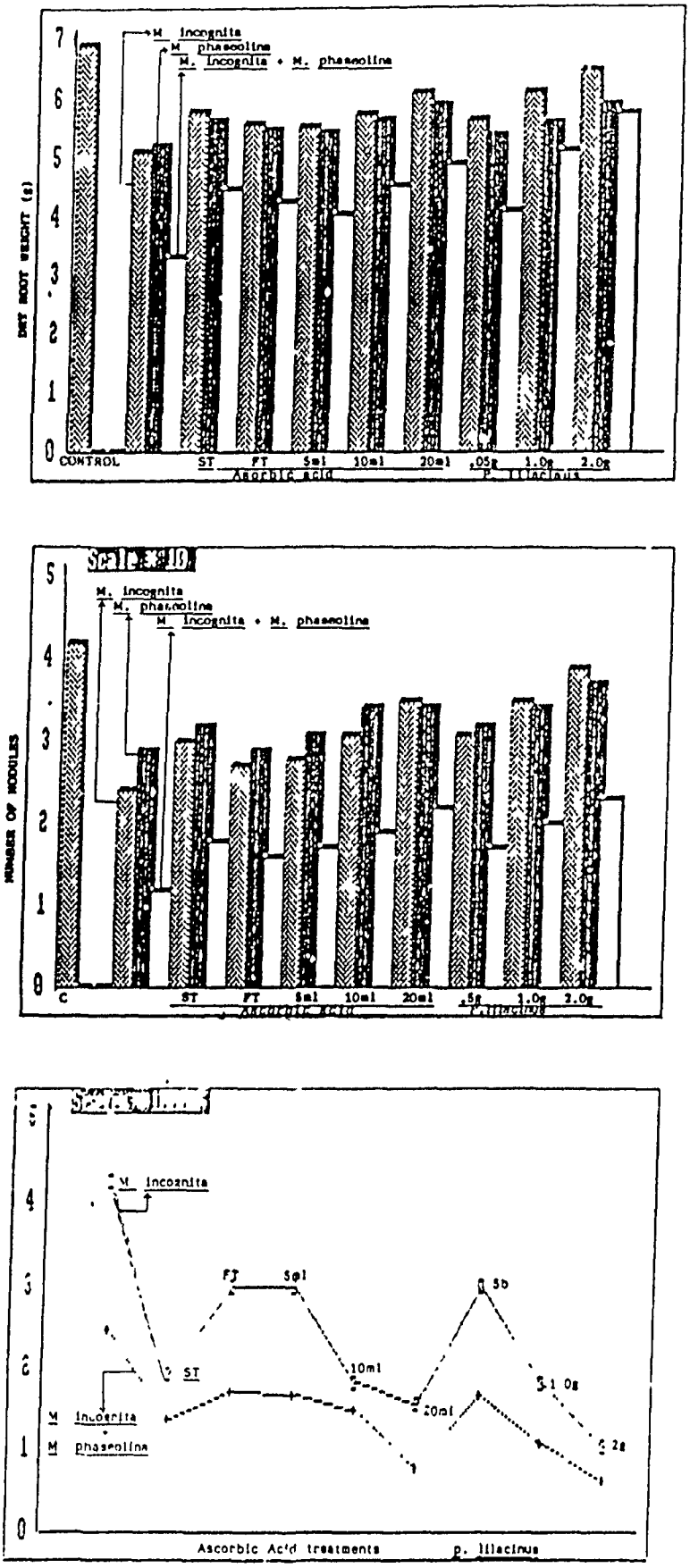


Fig 4. Effect of ascorbic acid and P. lilacinus on dry shoot weight, nodulation and nematode multiplication.

increased nodulation upto 27.59%. The two pathogens together caused 71.43% nodulation reduction but treatments with ascorbic acid and P. lilacinus increased nodulation by 33.33 to 91.67%.

C. Effect on nematode multiplication

Nematode multiplication was significantly suppressed in the presence of M. phaseolina (Appendix - V). Ascorbic acid (seed treatment, foliar spray, 5, 10 and 20 ml soil doses) and P. lilacinus (0.5, 1.0 and 2.0 gm) treatments of nematode inoculated plants reduced nematode multiplication by 54.97, 29.37, 29.37, 57.03, 63.66, 29.63, 57.01 and 75.44% respectively. In similar treatments of plants inoculated with both the pathogens the reductions in nematode multiplication were 43.76, 31.17, 31.84, 40.38, 68.43, 31.65, 56.26 and 74.01% respectively (Table - 5, Fig. 4).

In general P. lilacinus and ascorbic acid treatments were more efficacious against nematode whether present singly or with fungus, than against fungus alone. Paecilomyces lilacinus was most effective in reducing nematode multiplication when used in high dose. In case of ascorbic acid,20 ml soil dose was best in reducing nematode multiplication as compared to its other treatments.

D. Root-knot and root-rot indices

Root-knot index was 5 in all the treatments except when nematode plus fungus inoculated plants were treated with 20 ml soil dose of ascorbic acid and 2.0 gm P. lilacinus or only nematode inoculated plants were treated with 2.0 gm P. lilacinus. Root-rot indices were 4 and 5 when plants were inoculated with M. phaseolina and M. phaseolina plus M. incognita respectively. It came down to 4 in the latter case when 2.0 gm P. lilacinus was used (Table - 5).

It is concluded that application of different doses and treatments were significantly more effective against nematodes, whether present singly or with M. phaseolina than against M. phaseolina. Growth improvement was significantly high when P. lilacinus treatments were given to plants concomitantly inoculated with both the pathogens than inoculated with either pathogen. Against M. phaseolina, only highest dose of P. lilacinus was significantly effective. As regards ascorbic acid treatments its higher soil doses and seed treatment were more effective in increasing growth of plants, infected either with nematode or with nematode and fungus, than the foliar spray and low soil dose treatments. Against M. phaseolina alone, only higher soil doses and seed treatment were significantly effective.

6. Studies on biological and herbal control of test pathogens

Leaf extracts of three plants namely Cymbopogon citratus (Lemon grass), Eichhornia crassipes (Water-Hyacinth) and Ipomea carnea, two bacteria (Bacillus licheniformis and Alkaligenes faecalis) and two fungi (Paecilomyces lilacinus and Acrophialophora fusispora) were used for the management of root-knot and root-rot diseases of chickpea.

There was significant improvement in growth of nematode inoculated plants when treated with medium and high doses of all the leaf extracts and biocontrol agents except A. faecalis (Appendix - VI). In case of fungus inoculated plants even the highest doses of B. licheniformis, A. fusispora and I. carnea were not able to improve plant growth significantly but improvement in plant growth was significant when fungus inoculated plants were treated with medium and high doses of C. citratus and only the high doses of E. crassipes and P. lilacinus. When plants were inoculated with both the pathogens, significant improvement in plant growth was observed where treatments were given with medium and high doses of C. citratus, E. crassipes, I. carnea, A. fusispora, P. lilacinus and B. licheniformis. No dose of A. faecalis was beneficial for plant growth though it reduced nematode multiplication (Plate - 4A&B).

Plate - 4A : Infection of Bacteria & Fungus on *M. incognita*

A = *B. licheniformis* (smear)

B = *A. faecalis* (smear)

C = Larva emerging from egg (infected with *B. licheniformis*).

D = Larva infected with *B. licheniformis*

4B

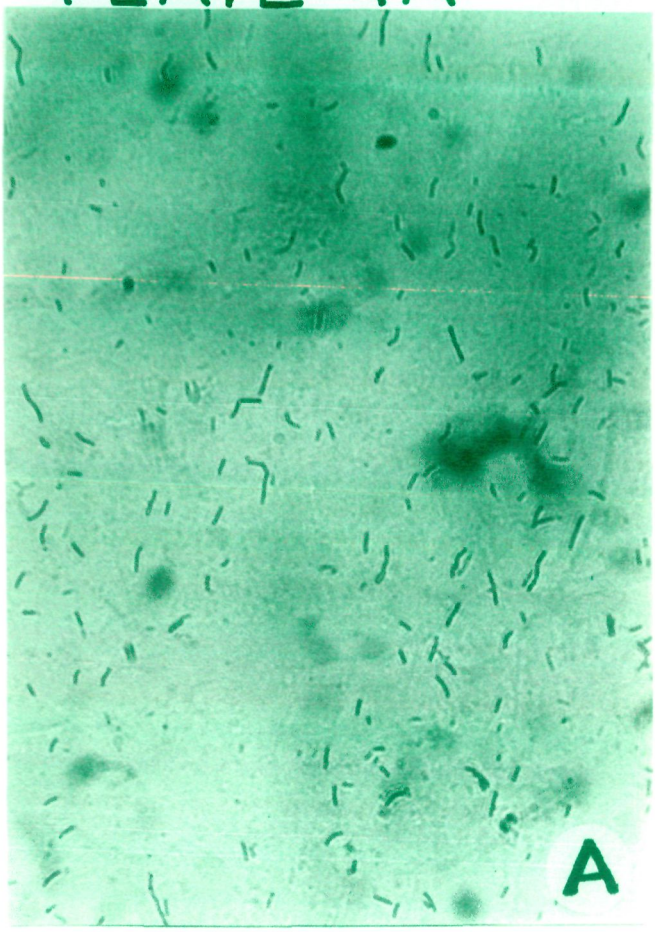
A = Female infected with *B. licheniformis*

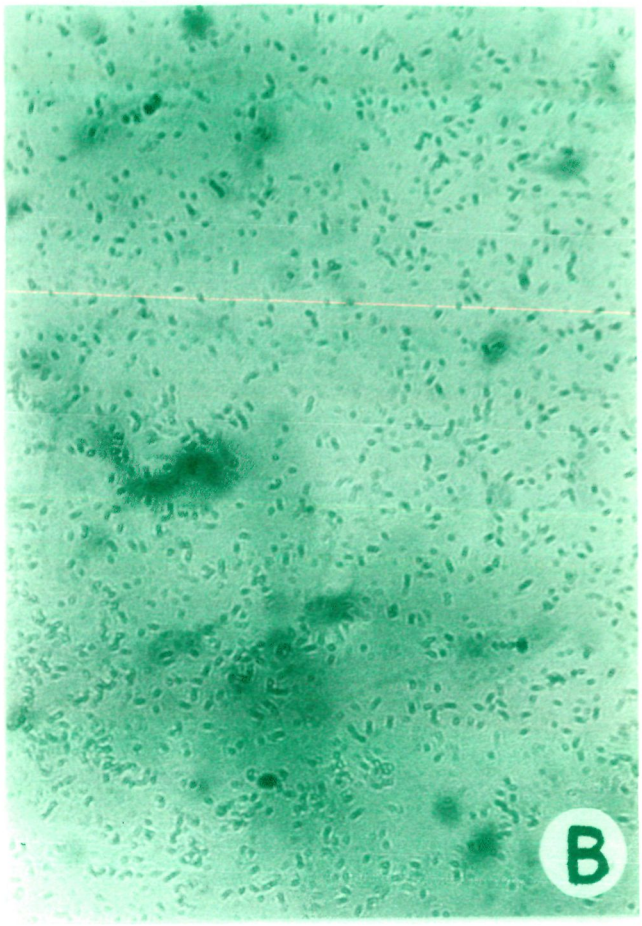
B = Eggs infected with *B. licheniformis*

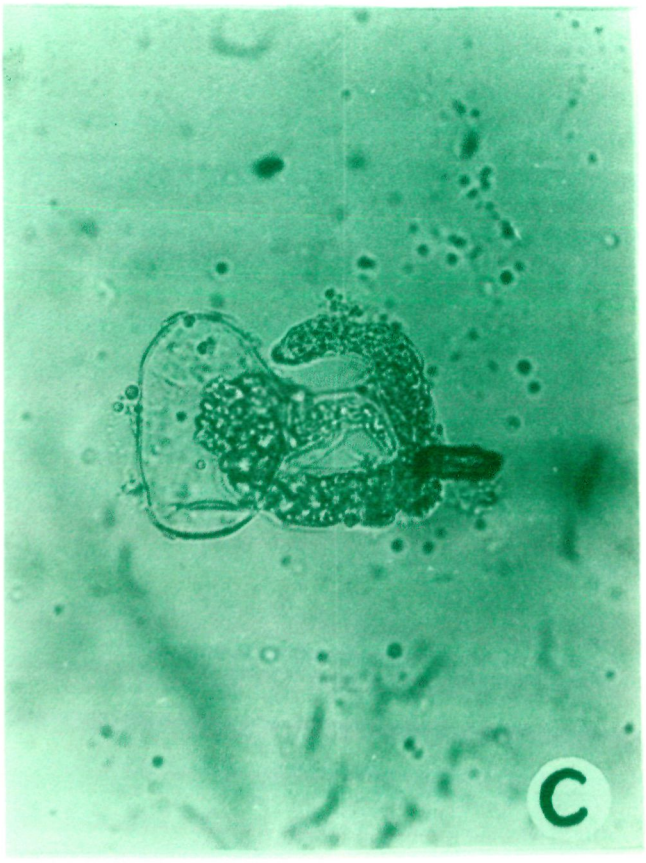
C = Portion of female showing *B. licheniformis* infection

D = Female infected with *A. fusispora*

PLATE-4A







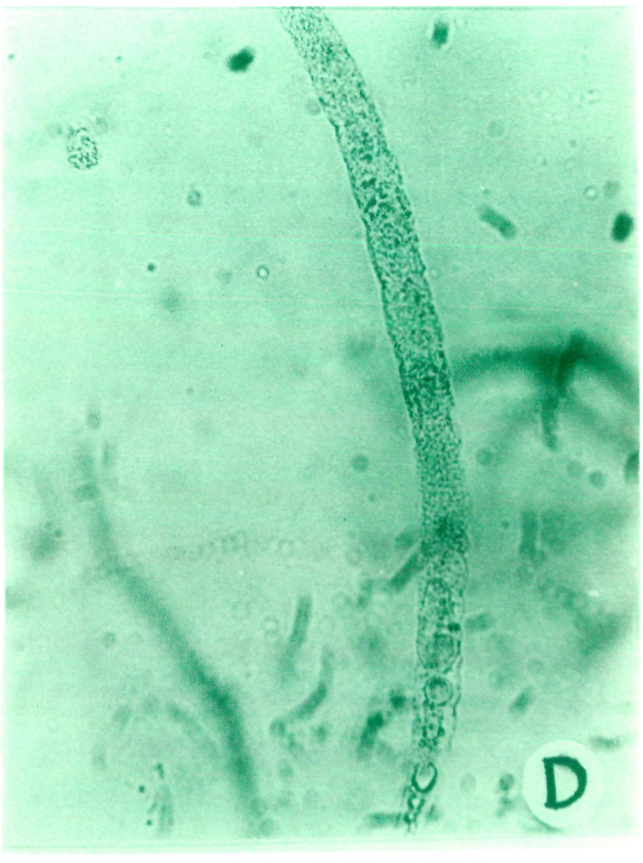
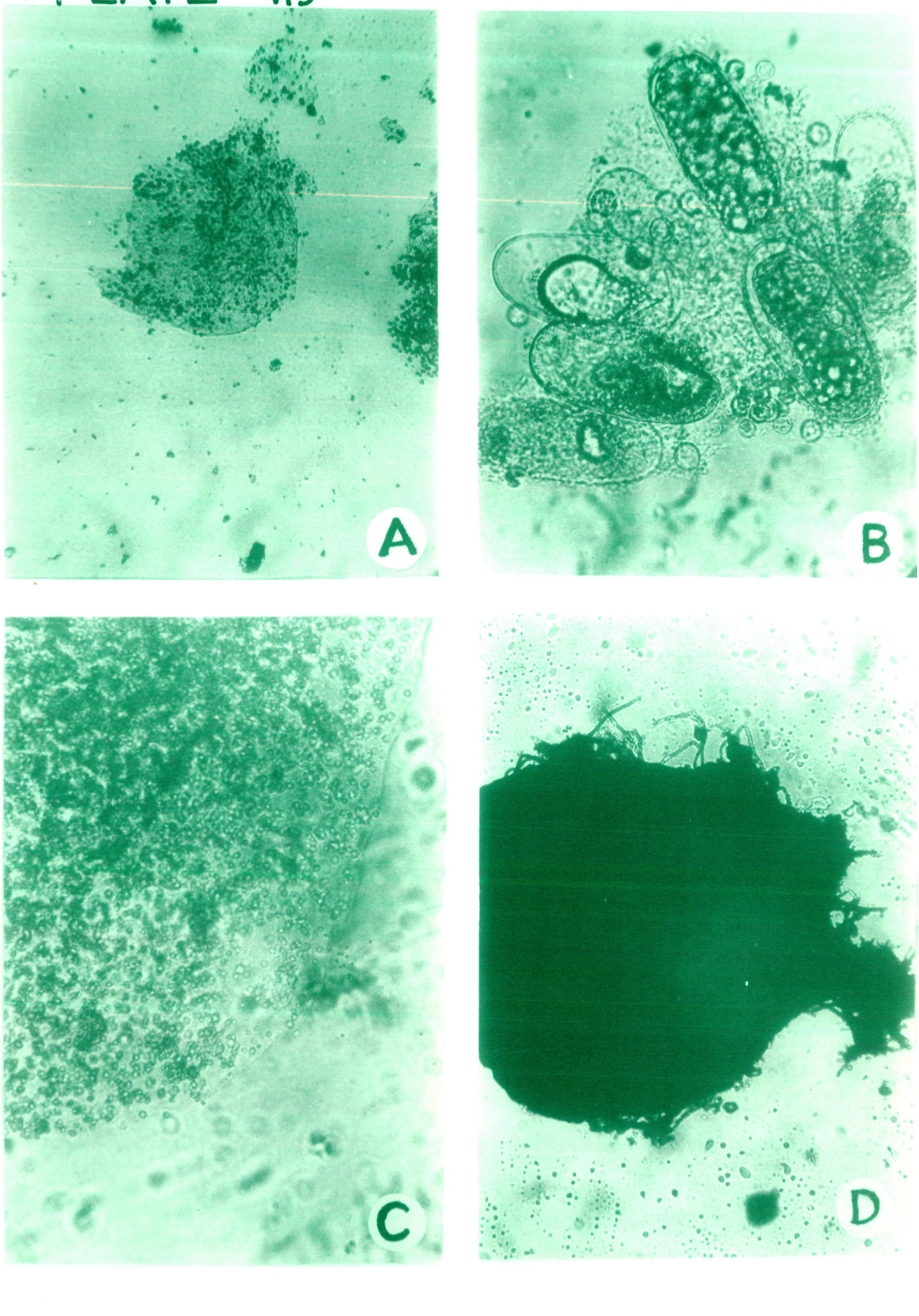


PLATE-413



There was significant improvement in nodulation when nematode inoculated plants were treated with high dose of E. crassipes and medium or high doses of other leaf extracts and biocontrol agents except A. faecalis. There was no significant improvement in nodulation of fungus inoculated plants treated with any dose of I. carnea, B. licheniformis and P. lilacinus but the medium and high doses of C. citratus, A. fusispora and only the high dose of E. crassipes improved nodulation significantly. In case of plants concomitantly inoculated with M. incognita and M. phaseolina, the application of all the doses of P. lilacinus, medium and high doses of C. citratus, E. crassipes, A. fusispora and B. licheniformis and only the high dose of I. carnea improved nodulation significantly.

A. Effect on dry shoot weight

Nematode alone caused 28.33% reduction in dry shoot weight of untreated plants but the application of medium and high doses of test materials caused significant improvement in dry shoot weight of inoculated plants. Improvement of plant growth was statistically not significant when treatments with low doses were given (Appendix - VI). Application of medium doses of P. lilacinus, C. citratus, E. crassipes, B. licheniformis, A. fusispora and I. carnea resulted in an increase of 22.56, 21.12, 18.05, 16.25, 16.06 and 14.98% dry shoot weight respectively over the nematode

inoculated control while their high doses improved growth of nematode infected plants by 29.96, 27.62, 26.90, 27.80, 22.56 and 21.30% of dry shoot weight (Table - 6, Fig. 5). Statistically speaking, both medium and high doses of P. lilacinus, C. citratus and E. crassipes were equally effective in improving plant growth of nematode inoculated plants though percent increase in dry shoot weight due to the application of P. lilacinus was apparently better than caused by the application of C. citratus and E. crassipes.

Macrophomina phaseolina caused 23.42% reduction in dry shoot weight of untreated plants but statistically significant improvement in plant growth was observed only when medium and high doses of C. citratus (i.e. 15.20 and 20.61% increase in dry shoot weight over inoculated control) and only the high doses of E. crassipes and P. lilacinus (20.95-14.53%) were applied to fungus inoculated plants (Table - 6, Fig. 5).

Reduction in dry shoot weight was 52.26% when both the pathogens were inoculated together. Application of medium doses of P. lilacinus, C. citratus, E. crassipes, I. carnea, A. fusispora and B. licheniformis to the plants concomitantly inoculated with both the pathogens caused 53.66, 47.70, 42.82, 39.84, 27.37 and 24.39% increase in their dry shoot weight whereas their corresponding high

Table-6. Effect of leaf extracts and biocontrol agents on dry shoot reduction, nodulation and nematode multiplication

Treatment		1	2	3	4	5	6	7
C		-	-	-	-	-	-	-
MI		28.33	-	40.91	-	-	5	-
MP		23.42	-	34.09	-	-	-	4
MI+MP		52.26	-	68.18	-	-	5	5
C. citratus								
MI		21.35	9.75	29.55	19.23	15.36	5	-
MP	5 ml	19.28	5.41	22.73	17.24	-	-	4
MI+MP		42.17	21.14	58.82	35.71	27.09	5	5
MI		13.20	21.12	20.45	34.62	44.14	5	-
MP	10 ml	11.77	15.20	15.91	27.59	-	-	3
MI+MP		29.50	47.70	45.45	71.43	53.52	4	5
MI		8.54	27.62	20.45	34.62	65.80	5	-
MP	20 ml	7.63	20.61	11.36	34.48	-	-	2
MI+MP		20.44	66.67	40.91	85.71	66.59	4	4
E. crassipes								
MI		22.12	8.66	36.36	7.69	14.26	5	-
MP	5 ml	18.63	6.25	27.27	10.34	-	-	4
MI+MP		42.69	20.05	61.36	21.43	24.10	5	5
MI		15.39	18.05	31.82	15.38	38.00	5	-
MP	10 ml	13.32	13.18	22.73	17.24	-	-	3
MI+MP		31.82	42.82	54.55	42.86	47.25	5	5
MI		9.06	26.90	22.73	30.77	59.19	5	-
MP	20 ml	7.37	20.95	20.45	20.69	-	-	2
MI+MP		22.12	63.14	47.73	64.29	60.62	4	4
I. carnea								
MI		22.64	7.94	34.09	11.54	9.77	5	-
MP	5 ml	21.73	2.20	27.27	10.34	-	-	4
MI+MP		42.95	19.51	63.64	14.29	15.16	5	5
MI		17.59	14.98	22.73	30.77	34.16	5	-
MP	10 ml	18.76	6.08	22.73	17.24	-	-	4
MI+MP		33.25	39.84	56.82	35.71	38.96	5	5
MI		13.07	21.30	18.18	38.46	54.43	5	-
MP	20 ml	12.94	10.97	22.73	17.24	-	-	3
MI+MP		23.54	60.16	52.27	50.00	52.52	5	4
P. lilacinus								
MI		20.44	11.01	29.55	19.23	38.18	5	-
MP	0.5 gm	22.77	00.84	29.55	6.90	-	-	4
MI+MP		41.66	22.22	54.55	42.85	34.81	5	5

Treatment		1	2	3	4	5	6	7
MI		12.16	22.56	20.45	34.62	56.76	5	-
MP	1.0 gm	20.05	4.39	25.00	13.79	-	-	4
MI+MP		26.65	53.66	45.45	71.43	56.97	5	5
MI		6.86	29.96	11.36	50.00	74.88	4	-
MP	2.0 gm	12.29	14.53	22.73	17.24	-	-	4
MI+MP		17.46	72.90	38.64	92.86	70.00	4	4
A. fusispora								
MI		24.45	5.42	29.55	19.23	18.53	5	-
MP	5 gm	20.70	3.55	25.00	13.79	-	-	4
MI+MP		46.96	11.11	61.36	21.43	30.49	5	5
MI		16.82	16.06	22.73	30.77	41.50	5	-
MP	10 gm	18.89	5.91	20.45	20.69	-	-	4
MI+MP		39.20	27.37	54.54	42.86	49.46	5	5
MI		12.16	22.56	13.64	46.15	62.24	5	-
MP	20 gm	16.82	8.61	20.45	20.68	-	-	4
MI+MP		29.24	48.24	40.91	85.71	61.38	4	5
A. faecalis								
MI		32.73	-6.14	45.45	-7.69	8.30	5	-
MP	5 ml	29.24	-7.60	40.91	-10.34	-	-	5
MI+MP		54.33	-4.34	77.27	-28.37	22.37	5	5
MI		36.48	-11.37	45.45	-7.69	28.49	5	-
MP	10 ml	33.51	-13.18	47.23	-20.69	-	-	5
MI+MP		55.50	-6.78	77.27	-28.57	39.23	5	5
MI		41.14	-17.87	56.82	-26.92	44.66	5	-
MP	20 ml	38.68	-19.93	52.27	-27.59	-	-	5
MI+MP		58.86	-13.82	81.82	-42.86	48.81	5	5
B. licheniformis								
MI		24.71	5.05	34.09	11.54	13.29	5	-
MP	5 ml	21.47	2.53	29.55	6.90	-	-	4
MI+MP		45.41	14.36	59.09	28.57	23.28	5	5
MI		16.69	16.25	27.27	15.38	36.59	5	-
MP	10 ml	19.66	4.90	31.82	10.34	-	-	4
MI+MP		40.62	24.39	54.55	42.86	45.69	5	5
MI		8.41	27.80	18.18	38.46	52.79	5	-
MP	20 ml	14.88	11.15	22.72	17.41	-	-	3
MI+MP		31.18	44.17	45.45	71.43	54.37	5	5

1 - % decrease in DSW over uninoculated control
2 - % increase in DSW over inoculated control
3 - % decrease in nodulation over uninoculated control
4 - % increase in nodulation over inoculated control
5 - % decrease in nematode multiplication
6 - Root-knot index 7 - Root-rot index
MI - Meloidogyne incognita MP - Macrophomina phaseolina

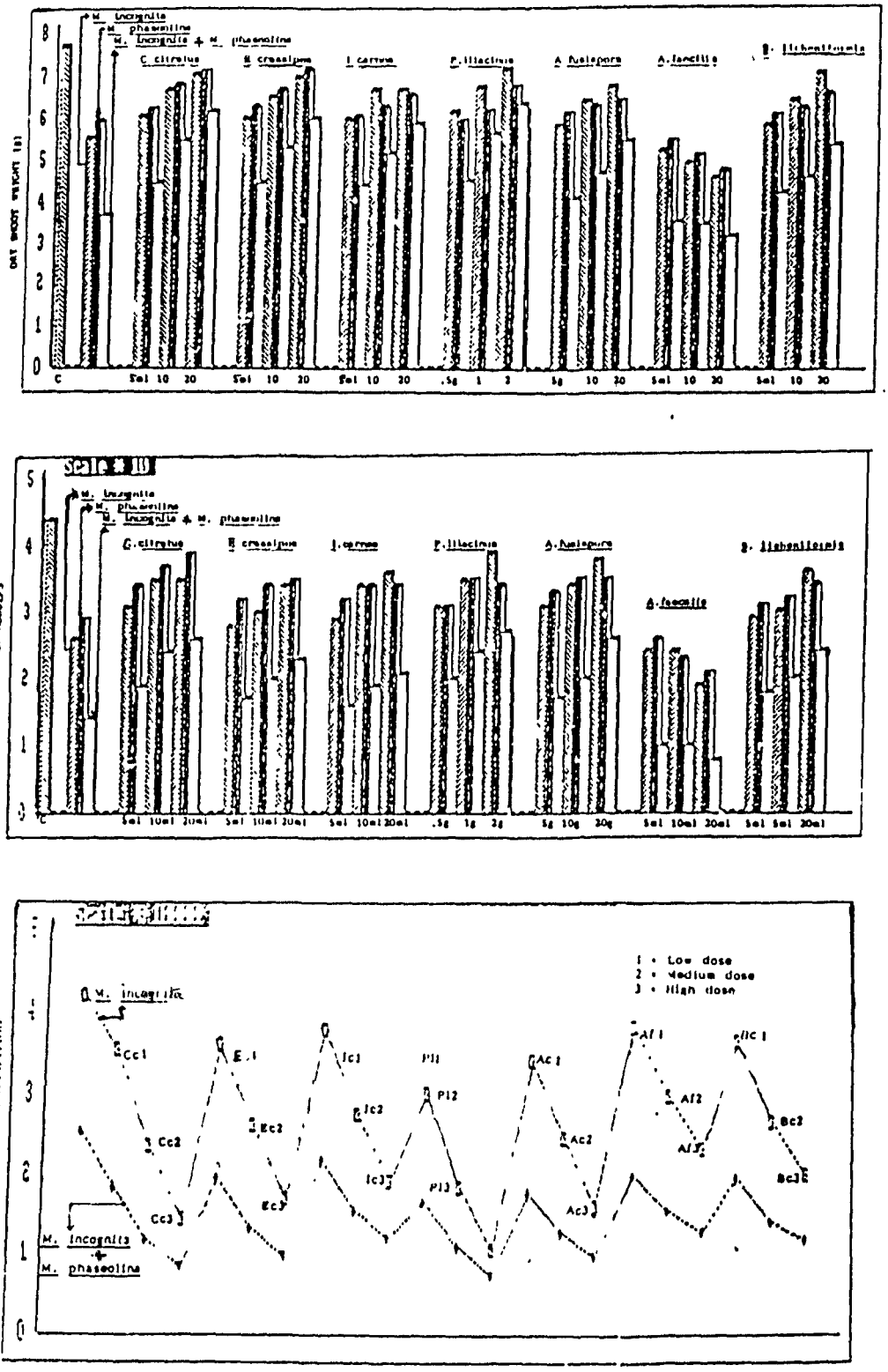


Fig 5. Effect of different doses of leaf esxtracts and biocontrol agents on dry shoot weight, nodulation and nematode multiplication.

doses improved plant growth by 72.90, 66.67, 63.14, 60.16, 48.24 and 44.17%.

B. Effect on nodulation

Nematode parasitism caused 40.91% nodulation reduction but the application of different doses of leaf extracts and biocontrol agents except A. faecalis exerted beneficial effect on nodulation. Percentage increase in nodulation were 7.69 to 19.23, 15.38 to 34.62 and 30.77 to 50.00 when the low, medium and high doses of the test materials were *applied against nematode inoculated plants respectively* (Table - 6, Fig. 5).

M. phaseolina when present alone caused 34.09% reduction in nodulation but nodulation was increased by 6.90 to 17.24, 13.79 to 27.59 and 17.24 to 34.48% over inoculated control when low, medium and high doses of test materials (except A. faecalis) were applied.

The test pathogens when present together caused 68.18% reduction in nodulation. Percentage increases in nodulation were 14.29 to 42.85, 35.71 to 71.43 and 50.00 to 92.86% when low, medium and high doses of test materials (except A. faecalis) were applied (Table - 6, Fig. 5).

Paecilomyces lilacinus was best in improving nodulation against plants inoculated with nematodes alone and nematode plus fungus but C. citratus was best against fungus when present alone.

C. Effect on nematode multiplication

Application of all test materials significantly reduced nematode multiplication. Low doses of test materials resulted in 8.30 to 38.18% reduction in nematode population compared to plants having nematode alone while medium and high doses resulted in 28.49 to 56.76% and 44.66 to 74.88% reduction in nematode population.

Plants inoculated with both the pathogens when treated with test materials also significantly reduced nematode multiplication. Reductions in multiplication were 15.16 to 34.81, 38.96 to 56.97 and 52.52 to 70.00% when low, medium and high doses were used respectively (Table - 6, Fig. 5) Paecilomyces lilacinus was most efficacious at medium and high doses in reducing nematode multiplication and A. faecalis the least. Only high doses of C. citratus, A. fusispora, E. crassipes, B. licheniformis and I. carnea reduced nematode multiplication by more than 50%.

D. Root-knot and root-rot indices

Root-knot index was 5 when untreated plants were inoculated either with M. incognita or with M. incognita plus M. phaseolina. When the plants were inoculated with both the pathogens but treated with C. citratus (10 and 20 ml), E. crassipes (20 ml), P. lilacinus (2.0 gm) and A. fusispora (20 gm) the root-knot index came down to 4. In case of plants inoculated with only nematodes no other

material except P. lilacinus (2.0 gm dose), could bring down the root-knot index (Table - 6).

Root-rot indices of plants inoculated with M. phaseolina and M. phaseolina plus M. incognita were 4 and 5 respectively. When the fungus inoculated plants were treated with medium doses of C. citratus and E. crassipes the root-rot index was 3. When high doses of C. citratus, E. crassipes, I. carnea and B. licheniformis were given the root-rot indices were 2, 2, 3 and 3 respectively. The application of low and medium doses of no test material could bring down the root-rot index of plants concomitantly inoculated with both the pathogens while the high doses of C. citratus, E. crssipes, I. carnea and P. lilacinus reduced the root-rot index to 4.

It is concluded that P. lilacinus was the best management material both for nematode alone and the concomitant infections of M. incognita and M. phaseolina whereas C. citratus and E. crassipes were best against M. phaseolina alone. However, our results suggest that B. licheniformis and A. fusispora may also be used for management of nematodes (Plate - 4A&B).

7. Effect of culture filtrates on plant growth, nodulation, disease development and nematode multiplication

Commonly occurring soil fungi and their metabolites are most likely to influence the parasitism of pathogenic

organisms. In view of the above, the efficacy of soil doses in two concentrations (S and S/10) of the culture filtrates of six fungi namely Aspergillus niger, A. flavus, Alternaria brassicicola, A. triticina, Fusarium solani and Paecilomyces lilacinus was tested against the individual and combined infections of M. incognita and M. phaseolina.

Growth of nematode infected plants was significantly improved by the application of 'S' concentration of all the test fungi and both the concentrations of only A. niger and P. lilacinus filtrates but against M. phaseolina, only 'S' concentration of culture filtrates of A. niger, A. flavus and P. lilacinus could cause significant improvement in plant growth (Appendix - VII). On the other hand both the concentrations of culture filtrates of test fungi were beneficial in improving growth of plants concomitantly infected with both the pathogens (M. incognita and M. phaseolina).

Application of the 'S' concentration of culture filtrates of A. niger, A. flavus, F. solani and P. lilacinus significantly improved nodulation of nematode infected plants. Only A. niger improved nodulation of M. phaseolina infected plants while A. niger, F. solani and P. lilacinus improved nodulation of plants infected with both (Appendix - VII).

Application of both the concentrations of all the fungal filtrates significantly reduced nematode

multiplication, whether M. incognita was present alone or concomitantly with M. phaseolina.

A. Effect on dry shoot weight

Meloidogyne incognita, when present alone, caused 26.07% reduction in dry shoot weight but when the nematode inoculated plants were treated with S/10 concentration of A. niger and P. lilacinus the improvement in plant growth (i.e. increase in dry shoot weight) was 12.32 and 13.29% respectively. The improvement in plant growth was 21.74, 19.81, 14.98, 13.29, 12.08 and 11.11% when the 'S' concentrations of P. lilacinus, A. niger, A. flavus, A. brassicicola, A. triticina and F. solani were used respectively (Table - 7, Fig. 6).

The reduction in dry shoot weight due to parasitism of M. phaseolina was 23.57% but the application of 'S' concentrations of A. niger, A. flavus and P. lilacinus improved plant growth by 14.95, 13.32 and 14.49%. respectively.

Inoculation of both the pathogens together caused 53.75% reduction in dry shoot weight but the application of 'S/10' concentration of P. lilacinus, A. niger, A. flavus, A. brassicicola, A. trilicina and F. solani improved plant growth by 36.68, 34.75, 30.12, 24.32, 23.55 and 25.87% respectively while their 'S' concentrations caused 67.57, 65.25, 60.62, 54.83, 47.49 and 51.35% improvement in plant growth of infected plants.

Table-7. Effect of culture filtrates of some common soil fungi on dry shoot weight, nodulation and nematode multiplication

Treatment		1	2	3	4	5	6	7
C		-	-	-	-	-	-	-
MI		26.07	-	44.74	-	-	5	-
MP		23.57	-	34.21	-	-	-	4
MI+MP		53.75	-	60.53	-	-	5	5
A. niger								
MI		16.96	12.32	31.58	23.81	35.97	5	-
MP	S/10	16.61	9.11	21.05	20.00	-	-	4
MI+MP		37.68	34.75	52.63	20.00	45.17	5	5
MI		11.43	19.81	18.42	47.62	58.28	5	-
MP	S	12.14	14.95	10.53	36.00	-	-	3
MI+MP		23.57	65.25	39.47	53.33	62.39	4	4
A. flavus								
MI		20.18	7.97	31.58	23.81	32.36	5	-
MP	S/10	19.64	5.14	28.95	8.00	-	-	4
MI+MP		39.82	30.12	55.26	13.33	37.62	5	5
MI		15.00	14.98	21.05	42.86	54.75	5	-
MP	S	13.39	13.32	15.79	28.00	-	-	3
MI+MP		25.71	60.62	50.00	26.67	56.51	4	5
A. brassicicola								
MI		21.79	5.80	28.95	28.57	28.97	5	-
MP	S/10	20.54	3.97	23.68	16.00	-	-	4
MI+MP		42.50	24.32	57.89	6.67	30.17	5	5
MI		16.25	13.29	26.32	33.33	50.96	5	-
MP	S	18.21	7.01	21.05	20.67	-	-	4
MI+MP		28.39	54.83	50.00	26.67	54.51	5	5
A. triticina								
MI		23.04	4.11	36.84	14.29	22.01	5	-
MP	S/10	21.43	2.80	31.58	4.00	-	-	4
MI+MP		42.86	23.55	52.63	20.00	19.06	5	5
MI		17.14	12.08	26.32	33.33	43.14	5	-
MP	S	19.46	5.37	21.05	20.00	-	-	4
MI+MP		31.79	47.49	44.74	40.00	47.29	5	5
F. solani								
MI		23.57	3.38	34.21	19.05	23.98	5	-
MP	S/10	22.32	1.64	28.95	8.00	-	-	4
MI+MP		41.79	25.87	47.37	33.33	19.90	5	5

Treatment		1	2	3	4	5	6	7
MI		17.86	11.11	23.68	38.10	46.80	5	-
MP	S	17.72	8.18	21.05	20.00	-	-	4
MI+MP		30.00	51.35	36.84	60.00	45.50	5	5
P. lilacinus								
MI		16.25	13.29	26.32	33.33	39.25	5	-
MP	S/10	20.71	3.74	23.68	16.00	-	-	4
MI+MP		36.79	36.68	47.37	33.33	47.84	5	5
MI		10.00	21.74	13.16	57.14	60.92	5	-
MP	S	12.50	14.49	18.42	24.00	-	-	3
MI+MP		21.96	67.57	36.84	60.00	63.40	4	4

1 - % decrease in DSW over uninoculated control
2 - % increase in DSW over inoculated control
3 - % decrease in nodulation over uninoculated control
4 - % increase in nodulation over inoculated control
5 - % decrease in nematode multiplication
6 - Root-knot index 7 - Root-rot index
MI - *Meloidogyne incognita* MP - *Macrophomina phaseolina*

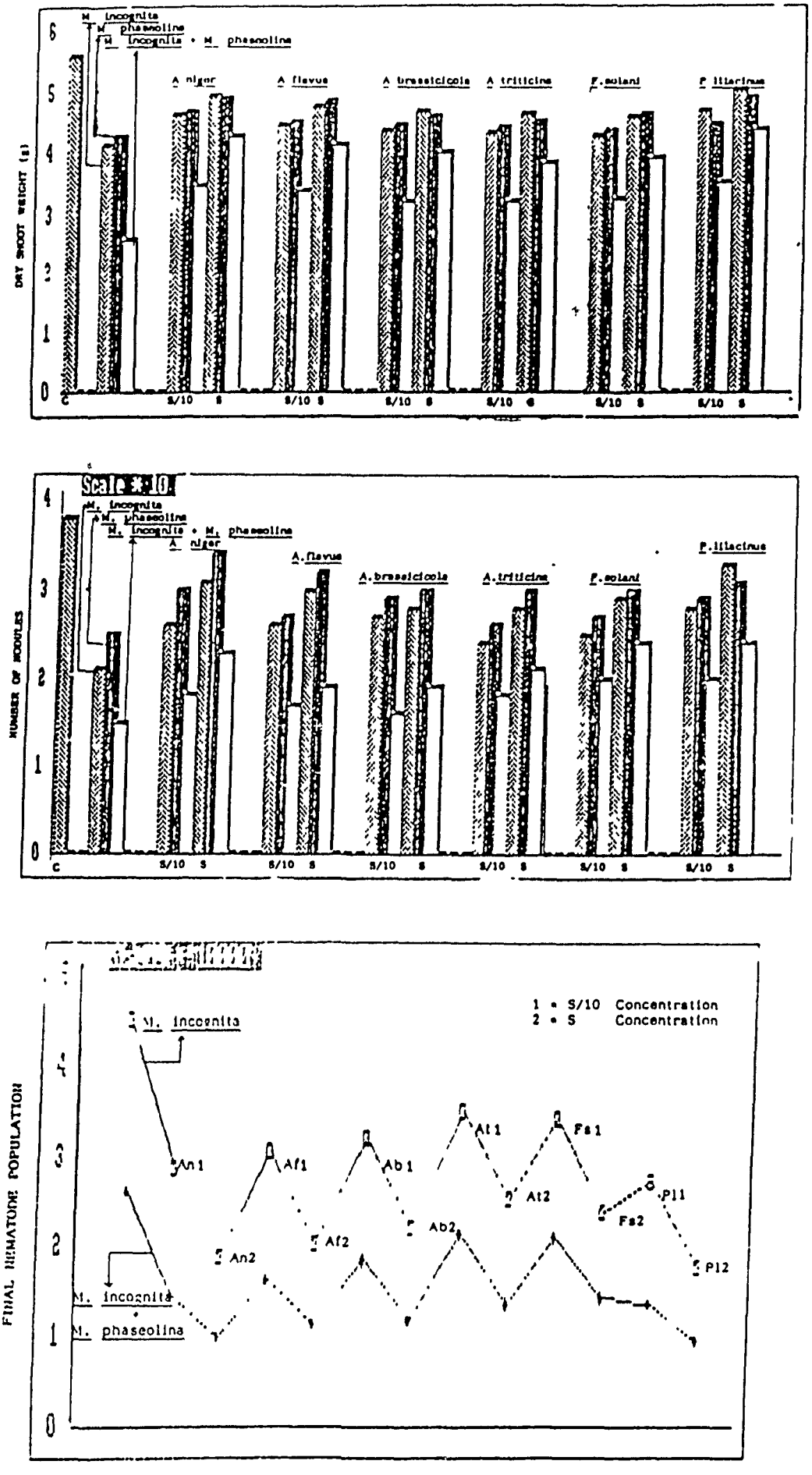


Fig 6. Effect of culture filtrates of some common soil borne fungi on dry shoot weight, nodulation and nematode multiplication.

B. Effect on nodulation

Meloidogyne incognita alone caused 44.74% reduction in nodulation but the application of 'S' concentrations of P. lilacinus, A. niger, F. solani and A. flavus caused 57.14, 47.62, 38.10 and 42.86% improvement of nodulation over inoculated control. Similarly, inoculation of M. phaseolina caused 34.21% reduction in nodulation but the 'S' concentration of A. niger increased nodulation by 36.00% over inoculated control (Table - 7, Fig. 6). The combined inoculations of M. incognita and M. phaseolina caused 60.53% reduction in nodulation. In this case the application of 'S' concentrations of F. solani, P. lilacinus and A. niger improved nodulation by 60.00, 60.00 and 53.33% respectively.

C. Effect on nematode multiplication

The application of 'S/10' concentrations of P. lilacinus, A. niger, A. flavus, A. brassicicola, F. solani and A. triticina reduced nematode multiplication by 39.25, 35.97, 32.36, 28.97, 23.98 and 22.01% respectively and their corresponding 'S' concentrations by 60.92, 58.28, 54.75, 50.96, 46.80 and 43.14% respectively. When the plants were inoculated with both the pathogens and treated with 'S/10' concentrations of P. lilacinus, A. niger, A. flavus, A. brassicicola, A. triticia and F. solani the reductions in nematode multiplication were 47.84, 45.17,

37.62, 30.17, 19.06 and 19.90% respectively. Application of these filtrates in 'S' concentration resulted in 63.40, 62.39, 56.51, 54.51, 54.51, 47.29 and 45.50% reductions in nematode multiplication (Table - 7, Fig. 6).

D. Root-knot and root-rot indices

Root-knot index was 5 whether plants were inoculated with M. incognita or with M. incognita plus M. phaseolina but the application of 'S' concentration of culture filtrates of A. niger, A. flavus and P. lilacinus reduced it to 4 in case of plants inoculated with both the pathogens (Table - 7). Root-rot indices were respectively 4 and 5 when plants were inoculated with M. phaseolina or with M. phaseolina and M. incognita together. Application of 'S' concentrations of A. niger, A. flavus and P. lilacinus filtrates brought down the root-rot index to 3 of M. phaseolina inoculated plants. However, application of the same concentration of A. niger and P. lilacinus to plants inoculated with both the pathogens reduced the root-rot index to 4.

It is concluded that culture filtrates of P. lilacinus and A. niger were effective for the management of nematode population when present alone or with M. phaseolina in both the concentration while these filtrates were also effective against M. phaseolina in S concentration.

DISCUSSION AND CONCLUSIONS

The economic threshold levels of Meloidogyne spp. on chickpea were earlier determined by several workers (Srivastava et al., 1974; Nath et al., 1979; Ram & Gupta, 1982; Mani & Sethi, 1984) but their findings have been at variance. Damaging threshold level as low as 200 juveniles of M. incognita and M. javanica per Kg soil was reported by Nath et al. (1979) and Srivastava et al. (1974) respectively but Ram & Gupta (1982) and Mani & Sethi (1984) found 1000 and 2000 juveniles of M. javanica and M. incognita as damaging threshold levels respectively. My findings are in conformity with those of Mani & Sethi (1984). The differences observed in damaging threshold levels by different workers can be attributed to the differences in experimental conditions, the cultivars used, or the species and races of the nematode involved.

Effect of nematode parasitism on nodulation has been reported stimulatory (Hussey & Barker, 1976), inhibitory (Miller, 1951; Masefield, 1958; High, 1966; Balasubramanian, 1971; Baldwin et al., 1975; Hussaini & Seshadri, 1975; Sharma & Sethi, 1976a, Bopaiah et al., 1976a; Singh et al., 1977; Srivastava et al., 1979; Raut, 1980; Chahal & Singh, 1984; Singh, 1984) or neutral (Taha & Raski, 1969). I, in my experiments, found it to be

inhibitory (Appendix - I, Table - 1). Reduction in nodulation has earlier been explained as due to nutritional interference, particularly carbohydrates, or physiological changes brought about by nematode infestation than due to competition for root invasion.

There was increase in the number of galls and final nematode population with the increase of inoculum level as earlier reported by Kaul & Sethi (1982) and Mani & Sethi (1984) on maize and chickpea respectively. Nematode population was found density dependent (Appendix - I, Table - 1, Fig. 1) as also reported earlier by (Chapman, 1959; Seinhorst, 1960; Oostenbrink, 1966; Dhawan & Sethi, 1976; Gupta & Yadav, 1979; Dhruj & Vaishnav, 1981; Salem & Eissa, 1981; Mishra & Gaur, 1981; Thakar & Yadav, 1985). The maximum multiplication at low inoculum level might have been due to less competition for food and space than at high inoculum level.

Increasing inoculums of M. phaseolina caused increased root-rotting and wilting and the resultant decrease in plant growth parameters (Plate - I). Similar effects caused by other fungal pathogens have also been reported (Azam, 1975; Varshney, 1982; Zakiuddin, 1984 and Khan, 1986). Nodulation reduction due to fungal parasitism has also been reported (Gupta, 1974; Orellana et al., 1976; Zambolim & Schenk, 1984).

Protein content, both in the shoot and root, was found to increase with the increasing inoculum of M. incognita or M. phaseolina (Appendix - IA, Fig. 1A). Although the amount of buffer soluble protein in shoot was more than in the root but the percentage increase was more in root than in the shoot. Inoculum level dependent increase in protein content of root and shoot as observed in my experiment, is in conformity with the findings of Upadhyay & Banerjee (1986) but contrary to them the percentage increase was more in root than in shoot. Chatterjee & Sukul (1981) had used increase in protein content of root as an index for evaluating root-knot infection in lady's finger. The increase in total protein due to nematode infection has been reported by others also (Hanks & Feldman, 1966; Daney et al. 1971; Sinh et al., 1978).

The peroxidase activity increased upto the inoculum of 2000 juveniles of root-knot nematode and 1.0 gm fungus (Appendix - IB, Fig. 1A). There was no further increase in peroxidase activity at higher inoculums. Increase in peroxidase activity is considered related to the defence mechanism of plants.

On the basis of my findings, it has, therefore, been concluded that the damaging threshold levels of M. incognita and M. phaseolina were respectively 2000 juveniles of the former and 1.0 gm culture of the latter.

Various combinations of variable inoculums of test pathogens caused significant decrease in plant growth parameters. Reduction in plant growth was directly proportional to the increase in inoculum of test pathogens (Appendix - II, Table - 2, Fig. 2). The effect of interaction of test pathogens on plant growth was synergistic (Plate - 2A&B). Synergistic effects of nematode and fungus interactions have been reported earlier also (Cauqil & Sheperd, 1970; Whitney, 1974; Vaishnav & Sethi, 1978; Sharma et al., 1980; Khan et al., 1980; Singh et al., 1981; Mauza & Webster, 1982; Tchatchoua & Sikora, 1983; Chahal & Chhabra, 1984). Nematode and fungus together affected nodulation more significantly than any one of them singly (Malek & Jenkins, 1954; Nigh, 1966; Hendrick & Southards, 1976; Mani & Sethi, 1986). Adverse effect of fungus on nematode multiplication, as observed in the present findings, has also been observed by others (Sakhuja & Sethi, 1986; Al-Hazmi, 1985). According to Powell (1971) the populations of migratory nematodes in general appear to increase as a result of interactions with fungi while those of sedentary nematodes are suppressed under similar conditions due to adverse effect on nematode penetration and direct fungus invasion of giant cells disrupting nematode feeding and subsequent reproduction within the host roots. Contrary to this Tu & Cheng (1971) observed favourable effect of M. phaseolina on reproduction of M. javanica in

kenaf roots when both pathogens were inoculated simultaneously to 5, 10 and 15 days old seedlings. This difference might be due to different host, nematode species or inoculation treatment involved.

Bacterized plants attained better growth and suffered less damage than unbacterized ones in the presence of one or both the pathogens (Appendix - III, Table - 3). It appears that legumes drive possible disease protection from their association with rhizobium due to increased nitrogen status which results in better plant growth. Reduced nematode damage of bacterized plants has also been reported by others (Bopaiah et al., 1976a,b; Sharma & Sethi, 1976a; Upadhyay & Kumar, 1983). However, the findings contrary to this are not uncommon (Ali et al., 1981; Varshney, 1982). Reduced damage of bacterized plants due to fungal pathogens has also been reported (Drapeau et al., 1973; Chou & Schmitthner, 1974; Tu, 1978, 1980). Least plant damage occurred when rhizobium was added 10 days prior to one or both the pathogens but the maximum when pathogen inoculation was followed by rhizobium (Appendix - III, Table - 3, Fig. 3). In case of simultaneous inoculations the plant damage was of intermediate order (Plate - 3A&B). It was possibly because the prior establishment of rhizobium resulted in improved plant growth enabling the plants to restrict the pathogen activity. In case of prior inoculation of pathogens, when nematode was inoculated first and rhizobium and fungus 10 days later, the damage was very high probably because of

physiological and biochemical changes that generally occur in the host tissues as well as in the rhizosphere due to prior nematode establishment resulting in predisposition of plants to fungal attack (Reynolds & Hanson, 1959; Batten & Powell, 1971; Tu & Cheng, 1971; Hutton et al., 1973; Pitcher, 1974; Goswami et al., 1975; Malekaberhan & Evans, 1981; Negron et al., 1982; Al-Hazmi, 1985; Goel & Gupta, 1986 and Mani & Sethi, 1987). Michell & Powell (1972), Chhabra et al. (1977), Reddy et al., (1979) and Patel et al. (1987) on the other hand, reported higher damage when plants were simultaneously inoculated with nematode and fungus. This apparently different relationship might be attributed to the involvement of different species of nematode and fungus, different crops and sets of experimental conditions etc. In treatments where fungus was inoculated first and rhizobium and nematode 10 days later the damage was less than in case of simultaneous inoculation probably because the fungus parasitized the plants less vigrously when present alone than in the presence of nematode. Moreover, prior establishment of fungus reduced nematode multiplication more significantly. When rhizobium and nematode were inoculated first followed by fungus the damage was less compared to prior nematode inoculation followed by rhizobium and fungus 10 days later because of some protection provided by prior establishment of rhizobium. The same pattern was observed when rhizobium and fungus were inoculated prior to nematode (Appendix-III, Table-3, Fig. 3).

Multiplication of nematode was adversely affected by the presence of fungus as discussed earlier. Rhizobium also adversely affected nematode multiplication. Nodulation was also adversely affected by the parasitism of test pathogens when rhizobium was inoculated simultaneously or after the pathogen as discussed earlier but the inoculation of rhizobium prior to pathogens caused no significant reduction in nodulation because of its favourable effect on the plant growth which restricted pathogen's entry to some extent.

Sixty five chickpea vars. were screened separately for their resistance and susceptibility against M. incognita and M. phaseolina on the basis of modified Husain's (1986) resistance ratings. When evaluated on the basis of percentage reduction in dry shoot weight, nematode multiplication and root-knot and root-rot indices, no variety was found resistant or moderately resistant against either pathogen. One var. gave tolerant response against M. incognita and 7 against M. phaseolina. Thirty three vars. showed susceptible response against M. phaseolina and 37 against M. incognita. Twenty seven vars. were found highly susceptible against M. incognita and 25 against M. phaseolina (Appendix - IV, Table - 4). In most nematological studies varietal screening has been done on the basis of reduction in dry weight and nematode multiplication (Sandhu et al., 1981; Mani & Sethi, 1985; Khan & Khan, 1987; Sasser et al., 1987; Thakar et al., 1987;

Mishra & Gaur, 1989) but in the present study I employed two more parameters namely buffer soluble protein content and peroxidase activity.

Peroxidase is known as a key enzyme required for lignin synthesis and lignin is one of the compounds judged to be phytoalexin which plays a decisive role in disease resistance. Peroxidase catalyses several reactions including those involved in metabolism of phenols and indoles. Protein content of galled roots has earlier been used as an idex of root-knot nematode infestation in lady's finger (Chatterjee & Sukul, 1981). It is well known that qualitative protein changes occur in infected plants and the proteins may be of plant and/or pathogen origin. Therefore, the final resistance ratings were done on the basis of similarity of atleast two parameters.

When ratings were done on the basis of increase in protein content, no var. gave resistant reaction against nematode but one was evaluated resistant against M. phaseolina. Ten vars. were found tolerant against M. phaseolina and 9 against M. incognita whereas 30 were rated susceptible against M. incognita and 35 against M. phaseolina. Twenty six vars. were highly susceptible against M. incognita and 19 against M. phaseolina (Table - 4A). In this case increase in protein content was more in highly susceptible vars. followed by in susceptible, tolerant, moderately resistant and resistant vars. Uritani

& Stahmann (1961) reported increase in protein content of fungus infected tissues while Sharma et al. (1980), Basu & Sukul (1983) and Simte & Dasgupta (1987a) reported increase in protein content of nematode infected plants. Upadhyay & Banerjee (1986) reported inoculum level dependent increase in protein content of both shoot and root of M. javanica infected plants over uninoculated check which agrees with my findings of more significant increase in the highly susceptible vars. (highly infected plants) than in susceptible, tolerant, moderately resistant and resistant plants. However, my finding differs with those of Masood & Husain (1975) and Arya & Tiyagi (1982) who reported more protein in resistant than in susceptible and highly susceptible plants.

One var. each was found tolerant against M. incognita and M. phaseolina when evaluated on the basis of increase in peroxidase activity. Twenty six vars. were found susceptible against M. incognita and 37 against M. phaseolina while 27 were rated highly-susceptible against M. phaseolina and 38 against M. incognita (Table - 4A). Peroxidase activity was found high in tolerant vars. followed by susceptible and highly susceptible vars. Noel & Mc Clure (1978) also observed greater peroxidase activity in resistant cotton cultivar clevewilt 6-3-5 than in susceptible M8 cultivar when infected by M. incognita. Similarly, Fehrman & Diamond (1967) observed a positive

correlation between peroxidase activity in different organs of potato plants and resistance against Phytophthora infestans. Veech & Endo (1970) also reported increase in activity of cytochrome oxidase and peroxidase in soybean infected with M. incognita. Increase in the activity of peroxidase after nematode infection was also reported by Hussey & Krusberg (1970), Acedo & Rohde (1971), Huang et al. (1971), Mote & Dasgupta (1979), Ganguly & Dasgupta (1981), Mohanty et al. (1986), Simte & Dasgupta (1987b). It appears that increase in peroxidase activity after infection with pathogen is in response to resistance activity of the plant. More is the increase in peroxidase activity more is the resistant response of the cultivar.

When all the three parameters were collectively considered for the final rating, only 2 vars. were found tolerant against M. incognita and 4 against M. phaseolina. Thirty four vars. gave susceptible reaction against M. incognita and 38 against M. phaseolina while 29 were found highly susceptible against M. incognita and 23 against M. phaseolina (Table - 4B).

Efficacy of ascorbic acid solution (0.1%), three leaf extracts, four biocontrol agents and six culture filtrates were tested for the management of root-knot nematode and root-rot fungus when present alone or concomitantly and compared with that of P. lilacinus.

Paecilomyces lilacinus significantly improved growth of nematode and nematode plus fungus infected plants in all my treatments but in case of M. phaseolina infected plants only high dose of P. lilacinus was significantly effective (Appendix - V, Table - 5, Fig. 4). Jatala et al. (1979, 1980, 1981) and Morgan-Jones et al. (1984) have also earlier demonstrated that P. lilacinus parasitized eggs, females and larvae of M. incognita and Globodera pallida leading to their eventual death. This results in less development of disease on the host plants thereby improving crop yield. Similar beneficial effects of P. lilacinus have been reported by many other workers (Godoy et al., 1983; Noe & Sasser, 1984; Vellanueva & Davide, 1984; Dickson & Mitchell, 1985; Davide & Zorilla, 1986; Shahzad & Ghaffar, 1987; Cabanillas et al., 1988; Khan & Husain, 1988b; Sharma & Trivedi, 1989). I also observed antifungal effect of P. lilacinus that led to improved growth of infected plants. The antagonistic effect of P. lilacinus on Rhizoctonia solani has earlier been reported by Khan & Husain (1988b). Antagonistic effect of P. lilacinus to M. phaseolina may be attributed to some toxic metabolites or enzymes released by P. lilacinus which inhibited growth of M. phaseolina. Paecilomyces lilacinus is known to produce β (1-3) gluconase (Domsch et al., 1980) and chitinase (Okafor, 1967) extracellularly which are key enzymes in the lysis of fungal cell wall (Mitchell & Allexander, 1963), while Arai et al.

(1973) isolated leucostatin and lilacin, two water soluble peptide antibiotics from Penicillium lilacinus (Paecilomyces lilacinus). Leucostatin is known to be active against gram positive bacteria and many fungi.

It has now been convincingly demonstrated by several workers that P. lilacinus is highly efficaceous biocontrol agent for nematode management and that its antifungal and antibacterial activity has also come to light. In this study too it was found best when compared with other management materials.

Various treatments of ascrobic acid caused variable degree of growth improvement of nematode infected plants (Appendix - V, Table - 5, Fig. 4). Ascorbic acid is known to inhibit lipid oxidation in roots which is so necessary for root-knot larvae to be pathogenic because when lipid oxidation is inhibited the nematode has to use its own lipid reserves resulting in decreased nematode activity and infectivity. The nematodes start aging and eventually die and the damage caused by nematodes is consequently reduced. Higher soil doses and seed treatments were more effective because of high inhibition of lipid oxidation at the site of infection. Foliar applications and 5 ml soil doses were not significantly effective against M. phaseolina. Arrigoni et al. (1975, 1977), on the other hand, visualized the role of ascorbic acid in disease resistance.

Several species of Cymbopogon have been reported to possess nematicidal properties (Prem Kumar & Nair, 1976; Sangwan et al., 1985 and Tiyagi et al., 1986). In the present study nematicidal and antifungal efficacy of C. citratus has been confirmed (Appendix - VI, Table - 6, Fig. 5). The nematicidal activity of C. citratus can be attributed to its major constituents such as citral (about 54-87%) citronellol, geraniol and mycine. Efficacy of leaf extracts of I. carnea and E. crassipes against the two test pathogens can also be attributed to their major chemical constituents such as polysaccharide ipomose, an anthracene glucoside and one water soluble toxic principle in I. carnea and high potash and chlorine contents in E. crassipes (Anonymous, 1952, 1954). There appears potential scope for the use of herbal materials in nematode control as these materials are cheap, readily available, generally non-toxic to mammals and easily applicable as dry crop residues, green manuring or as extracts etc. Eichhornia crassipes (Water-Hyacinth) and I. carnea are common, abundantly available, noxious plants which may prove to be of ample significance for management of nematode problems in India. Moreover, their large scale application in any form would also reduce their own menace as undesirable fast growing plants and their application as organic amendment, would also improve soil fertility. Similarly, other cheap, easily available, nematotoxic herbal materials may also be safely used for this purpose.

Application of medium and high doses of Bacillus licheniformis and Acrophialophora fusispora improved growth of plants infected with nematode alone and nematode plus fungus, Bacillus licheniformis appears to have improved growth of nematode infected plants by their nematode parasitism which adversely affected nematode multiplication and survival (Plate - 4A&B). Reduction in nematode multiplication by the parasitism of Bacillus penetrans/Pasteuria penetrans has been reported by several workers (Mankau & Imbriani, 1975; Mankau & Prasad, 1977; Brown & Nardmeyer, 1985; Bird & Brisbane, 1988; Jay Raj & Mani, 1988) Bacillus licheniformis was not found effective against M. phaseolina although B. subtilis A13 was earlier reported to improve growth of Sclerotium rolfsii infected plants (Broadbent et al., 1975, 1977). Acrophialophora fusispora also improved growth of nematode infected plants and plants infected with nematode and fungus together. Acrophialophora fusispora parasitized females and eggs resulting in blackening and rotting of females, thus reducing their multiplication. It was not able to improve growth of plants infected with fungus alone. Alkaligenes faecalis though reduced nematode multiplication (Plate - 4A&B) but was not able to improve growth of nematode or fungus or nematode plus fungus infected plants. This was probably due to its mild pathogenic effect on chickpea.

Husain (1988b) reported A. fusispora, P. mindocina and Bacillus sp. as three new biocontrol agents of root-knot and cyst nematodes. The identity of Bacillus sp. has now been finally established as B. licheniformis and that of P. mindocina as Alkaligenes faecalis. These three biocontrol agents also show sufficient promise for nematode population management.

Since nematodes and fungi are the common inhabitants of soil, their secretions and excretions might naturally affect each other in various ways. Studies were, therefore, conducted to study the effect of culture filtrates of six fungi. Out of six culture filtrates used, culture filtrates of A. niger and P. lilacinus in both concentrations were effective for nematode population management when present alone or concomitantly with the fungus (Appendix - VII, Table - 7, Fig. 6). My results concerning efficacy of A. niger are in agreement with those of Mankau (1969a,b), Desai et al. (1972), Alam et al. (1973), Gupta et al. (1975), Khan et al. (1984a,b) and Vaishnav et al. (1985). Mankau (1969a) reported that A. niger filtrates showed strong positive test for oxalic acid and the toxic principle was thermostable. Aspersillus niger filtrate, in my study, also showed antifungal activity. Paecilomyces lilacinus culture filtrate was also found nematicidal and antifungal. Nematicidal and antifungal activity of P. lilacinus can be attributed to its

toxic metabolites or enzymes released by it such as β (1-3) gluconase, chitinase, leucostatin and lilacin (Domsch et al., 1980; Okafor, 1967; Mitchell & Allexander, 1963; Arai et al., 1973). The 'S' concentration of A. flavus was found toxic against nematodes. Nematotoxicity of A. flavus was also reported by Khan et al. (1984) and Vaishnav et al. (1985) but it was found less nematicidal than A. niger in the present studies. Culture filtrates of A. triticina, A. brassicicola and F. solani were less effective both against nematode and fungus individually or when present together.

When compared with all other test materials, P. lilacinus was found best for nematode population management. However, extracts of C. citratus and E. crassipes, cultures of B. licheniformis and A. fusispora, ascorbic acid and filtrate of A. niger can also be used either alone or in combination for management of root-knot nematode and root-rot fungus.

SUMMARY

1. Pathogenicity tests were conducted using five different inoculums each of M. incognita and M. phaseolina on chickpea. Both pathogens adversely affected plant growth and nodulation. However, damaging threshold level of M. incognita consisted of 2000 juveniles and that of M. phaseolina 1 gm culture per Kg soil. Peroxidase and buffer soluble proteins of similarly treated plants were also determined. Protein contents, both in shoot and root, increased with the increase in the inoculum level of the test pathogens. On the other hand, increase in peroxidase activity was observed only upto 2000 root-knot nematode juveniles and 1 gm fungus. The rate of nematode multiplication was, however, density dependent but root galling increased with the increase in the nematode inoculum level. Effect of nematode and fungus parasitism on nodulation was inhibitory.

2. Disease severity increased with the increasing inoculums and various combinations of variable inoculums of the two pathogens exerted synergistic effect on plant growth. However, increase in the inoculum level of M. phaseolina resulted in progressive decrease in nematode multiplication and root galling. On the other hand root-rotting increased with the increase in the combined inoculums of M. phaseolina and M. incognita. Combined high

inoculums of both test pathogens completely supressed nodulation.

3. Presence of rhizobium reduced the damage caused by test pathogens presumably because legumes derive disease protection from their association with rhizobium. Prior inoculation of rhizobium was best followed by simultaneous inoculation and inoculation of test pathogens followed by rhizobium. Inoculation of nematode followed by rhizobium and fungus 10 days later caused more damage than caused by other treatments. Apparently, prior inoculation of nematodes predisposed the plants for fungal attack resulting in aggravated damage.

4. Out of sixty five chickpea vars. screened, only one var. (IC-4944) gave tolerant response against M. incognita and 7 against M. phaseolina when rated on the basis of dry shoot weight reduction and nematode multiplication. On the basis of peroxidase activity only one var. each was found tolerant against M. incognita (IC-4953) and M. phaseolina (IC-4928). When ratings were done on the basis of increase in protein content the var. JG-315 was found resistant against M. phaseolina while ten vars. gave tolerant response against M. phaseolina and 9 against M. incognita. When final rating was done using the three parameters together, 2 vars. (IC-4944 and IC-4953) were found tolerant against M. incognita and 4 vars. (IC-4919, IC-4928, IC-4942 and

IC-4951) against M. phaseolina. Others were susceptible or highly susceptible.

5. Ascorbic acid treatments were more effective against M. incognita when present alone or with M. phaseolina but less effective against M. phaseolina. High soil dose (20 ml per pot) was most effective followed by seed treatment, 10 ml soil dose, foliar spray and 5 ml soil dose.

6. Out of the three leaf extracts used, Cymbopogon citratus was best followed by Eichhornia crassipes and Ipomea carnea against nematode and nematode plus fungus. Against M. phaseolina alone E. crassipes was most effective.

7. Out of four biocontrol agents used, Paecilomyces lilacinus was best. Bacillus licheniformis and Acrophialophora fusispora were almost equally effective against nematode alone or when present with fungus. Bacillus licheniformis and A. fusispora were not significantly effective against M. phaseolina when present alone but P. lilacinus was effective only when applied in high dose. Alkalingenes faecalis though reduced nematode multiplication but had adverse effect on plant growth.

8. Out of six culture filtrates used, both the 'S' and 'S/10' concentrations of Aspergillus niger and Paecilomyces lilacinus filtrates were more significantly effective in reducing damage caused by nematodes and nematode plus fungus

whereas only 'S' concentrations were significantly effective against M. phaseolina.

9. Out of all the materials used P. lilacinus gave the best results. However, C. citratus, E. crassipes, B. licheniformis, A. fusispora, ascorbic acid treatments (20 ml soil dose and seed treatment), culture filtrates of A. niger and P. lilacinus may also be used singly or in combination with other control measures for the management of root-knot and root-rot pathogens of chickpea.

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* original not seen.

Appendix - I *Effect of different inoculum levels of test pathogens on plant growth, nodulation, disease development and nematode multiplication.*

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
Control	47.70	21.00	28.85	20.46	6.30	1.83	34	-	-	-	-	-
MI-500	45.57	19.20	26.93	18.64	5.69	1.67	25	180	345	14340	4750	19445
MI-1000	43.77	18.10	25.15	17.70	5.18	1.56	22	225	460	25160	5680	31300
MI-2000	39.73	16.67	22.19	15.59	4.69	1.28	19	302	752	36130	7460	44342
MI-4000	35.70	14.27	19.61	15.64	4.22	1.04	17	417	960	44610	9140	54740
MI-8000	31.57	14.27	16.37	16.32	3.47	0.88	13	506	1346	59290	12500	73136
P=.05	4.12	2.67	3.42	2.42	1.11	0.23	6.58					565.26
P=.01	5.86	3.80	4.87	3.44	1.58	0.32	9.35					822.39
MP-0.25	45.43	21.07	26.75	18.84	5.80	1.68	29	-	-	-	-	-
MP-0.50	43.57	19.40	25.88	17.62	5.31	1.57	24	-	-	-	-	-
MP-1.00	39.60	18.87	22.77	15.99	4.88	1.26	20	-	-	-	-	-
MP-2.00	35.63	17.03	20.13	14.14	4.12	1.13	17	-	-	-	-	-
MP-4.00	32.67	15.37	16.61	12.12	3.60	0.94	16	-	-	-	-	-
P=.05	3.62	2.21	2.77	2.64	0.80	0.29	8.05					
P=.01	5.14	3.15	3.94	3.75	1.14	0.41	11.45					

MI = Meloidogyne incognita; MP = Macrophomina phaseolina

Appendix - IA

Effect of different inoculum levels of test pathogene on buffer soluble protein content.

Treatment	Buffer soluble protein (mg.) in one gram shoot (fresh weight)	% increase in shoot	Buffer soluble protein (mg.) in one gram root (fresh wt.)	% increase in root
C	33.078		6.750	-
MI 500	33.660	1.76	7.145	5.85
MI 1000	34.623	4.67	7.342	8.77
MI 2000	35.611	7.66	7.692	13.96
MI 4000	36.015	8.88	7.974	18.13
MI 8000	36.399	10.04	8.211	21.64
P=.05	0.489		0.253	
P=.01	0.696		0.359	
MP .25	33.783	2.13	6.987	3.51
MP .50	34.347	3.84	7.105	5.26
MP 1.00	35.482	7.27	7.382	9.36
MP 2.00	35.826	8.31	7.658	13.45
MP 4.00	36.179	9.37	7.934	17.54
P=.05	0.534		0.229	
P=.01	0.759		0.325	

MI = Meloidogyne incognita
MP = Macrophomina phaseolina

Appendix - IB

Effect of different inoculum levels of test pathogens on peroxidase activity.

Treatment	Peroxidase activity (unit/mg protein per minute) in shoot	Percentage increase	Peroxidase activity in root (Unit/ mg protein per minute)	Percentage increase
C	0.138	-	0.418	-
MI 500	0.141	2.17	0.468	11.96
MI 1000	0.146	5.80	0.490	17.22
MI 2000	0.148	7.25	0.496	18.66
MI 4000	0.148	7.25	0.473	13.16
MI 8000	0.147	6.52	0.462	10.53
P=.05	.005		.016	
P=.01	.007		.022	
MP .25	0.140	1.45	0.461	10.29
MP .50	0.142	2.90	0.481	15.07
MP 1.00	0.149	7.97	0.487	16.51
MP 2.00	0.147	6.52	0.469	12.20
MP 4.00	0.147	6.52	0.458	9.57
P=.05	.004		.008	
P=.01	.006		.011	

MI = *Meloidogyne incognita*

MP = *Macrophomina phaseolina*

Appendix - II Effect of interaction of variable inoculums of test pathogens on plant growth, nodulation, disease development and nematode multiplication.

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
Control	49.87	23.63	28.79	19.66	5.73	1.81	37	-	-	-	-	-
MI-500	47.68	21.45	26.95	18.76	5.20	1.69	28	177	339	14520	4690	19549
MI-1000	45.72	19.37	25.18	17.79	4.73	1.54	25	228	464	25070	5640	31174
MI-2000	41.58	18.60	22.22	15.65	4.27	1.31	23	297	746	36350	7420	44516
MI-4000	37.50	16.79	19.64	15.71	3.87	1.07	19	413	951	44280	9030	54261
MI-8000	32.09	14.60	16.39	16.40	3.18	0.91	14	502	1298	59110	12260	72668
MP=0.25	47.70	21.67	26.88	18.87	5.28	1.72	31	-	-	-	-	-
MP-0.50	45.52	19.72	25.86	17.68	4.84	1.60	28	-	-	-	-	-
MP-1.00	41.46	18.98	22.81	16.04	4.42	1.29	22	-	-	-	-	-
MP-2.00	37.28	17.43	20.20	14.22	3.76	1.13	19	-	-	-	-	-
MP-4.00	34.40	15.77	16.75	12.29	3.30	0.98	17	-	-	-	-	-
MP-0.25 + MI-500	45.47	21.33	24.63	17.13	4.86	1.54	24	158	304	12470	4815	17589
MP-0.25 + MI-1000	41.20	19.07	22.21	15.18	4.16	1.32	20	192	416	19345	5670	25431
MP-0.25 + MI-2000	37.17	16.90	19.21	13.32	3.46	1.01	18	260	670	28130	7820	36620
MP-0.25 + MI-4000	32.47	15.17	16.97	11.77	2.84	0.91	15	356	828	39750	9465	50043
MP-0.25 + MI-8000	28.27	13.63	14.83	9.82	2.22	0.84	11	435	1096	46280	11230	59606
MP-0.50 + MI-500	42.63	19.13	22.41	15.44	4.28	1.36	21	131	278	10110	4130	14518
MP-0.50 + MI-1000	38.43	17.53	19.16	13.48	3.76	1.07	17	167	364	16470	4960	21794
MP-0.50 + MI-2000	34.43	15.53	16.94	11.73	3.04	0.96	12	224	560	25830	7030	33420

Contd....

Appendix - II (Contd....)

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
MP-0.50 + MI-4000	30.60	13.47	15.19	10.32	2.38	0.75	8	308	645	33965	8890	43500
MP-0.50 + MI-8000	26.03	12.17	13.67	9.40	1.81	0.63	6	372	818	41440	11740	53998
MP-1.00 + MI-500	41.40	17.60	20.06	13.68	3.82	1.07	17	102	220	9780	3780	13780
MP-1.00 + MI-1000	37.23	15.70	18.30	11.86	2.98	0.95	12	145	305	13660	4650	18615
MP-1.00 + MI-2000	32.83	14.77	16.49	10.28	2.46	0.87	8	190	382	21940	6620	28942
MP-1.00 + MI-4000	28.07	12.53	14.87	8.81	1.92	0.76	5	252	526	29670	8160	38356
MP-1.00 + MI-8000	23.77	11.47	12.43	7.83	1.68	0.53	4	312	692	37920	10810	49422
MP-2.00 + MI-500	37.37	15.83	19.18	12.47	3.09	0.99	13	88	168	7260	2780	10208
MP-2.00 + MI-1000	33.77	13.63	17.11	10.06	2.56	0.85	8	128	252	11430	3940	15622
MP-2.00 + MI-2000	29.50	12.43	14.96	8.43	2.09	0.71	5	170	290	19760	5460	25510
MP-2.00 + MI-4000	25.33	10.70	12.48	7.75	1.65	0.58	2	224	434	26540	6975	33949
MP-2.00 + MI-8000	20.97	9.63	10.77	6.65	1.09	0.48	0	268	507	34780	8585	43872
MP-4.00 + MI-500	33.90	13.73	17.48	10.09	2.62	0.83	7	76	127	6180	2115	8422
MP-4.00 + MI-1000	29.50	12.50	13.84	8.50	2.04	0.65	4	109	174	9570	3060	12804
MP-4.00 + MI-2000	25.80	11.43	10.42	6.72	1.49	0.42	4	146	218	15120	4670	20008
MP-4.00 + MI-4000	22.27	9.50	7.79	5.04	0.91	0.38	0	178	282	21490	5910	27682
MP-4.00 + MI-8000	17.90	7.77	5.46	4.26	0.62	0.26	0	202	356	27220	7380	34856
P=.05	3.20	1.98	2.72	1.81	0.76	0.23	5.07					672.85
P=.01	4.25	2.63	3.61	2.40	1.01	0.30	6.73					894.89

MI = Meloidogyne incognita; MP = Macrophomina phaseolina.

Appendix - III Effect of individual, simultaneous, pre and post inoculation of test pathogens and rhizobium on plant growth, nodulation, disease development and nematode multiplication.

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root	ules		Females	Eggs	Larvae	Total
Control Bact.	47.27	22.87	30.41	20.51	5.77	1.88	39	-	-	-	-	-
Control Unbact.	43.27	20.83	27.56	18.73	5.07	1.62	0	-	-	-	-	-
MI-Unbact.	33.80	15.40	19.48	13.74	3.42	1.09	0	327	833	37960	7745	46538
MP-Unbact.	34.63	15.87	20.52	14.22	3.67	1.13	0	-	-	-	-	-
MI+MP-Unbact.	19.28	8.65	9.45	7.93	1.18	0.42	0	272	681	30890	5726	37297
MI+RH	38.83	17.97	23.63	15.85	4.29	1.39	28	291	710	33168	6090	33968
MP+RH	39.63	18.73	24.28	16.19	4.47	1.42	30	-	-	-	-	-
MI+MP+RH	28.87	13.53	16.36	11.23	2.83	0.90	19	216	398	20470	4165	25033
MI —— RH	35.37	16.80	21.97	14.44	3.82	1.20	24	316	776	35160	6330	42266
MP —— RH	36.30	17.10	22.60	15.07	3.98	1.24	24	-	-	-	-	-
MI+MP —— RH	26.73	12.33	14.06	9.48	1.79	0.59	16	229	415	24210	4240	28865
RH —— MI	40.53	19.63	25.09	16.57	4.76	1.53	34	256	682	31150	5265	37097
RH —— MP	41.73	20.13	25.68	16.92	4.95	1.57	36	-	-	-	-	-
RH —— MI+MP	30.23	15.10	18.18	12.96	3.43	1.08	26	182	338	18740	3730	22808
RH+MP —— MI	19.17	14.80	17.34	11.66	3.02	1.11	22	158	282	13780	2690	16752
RH+MI —— MP	25.23	12.30	15.52	10.71	2.05	0.79	23	238	436	23885	4015	28336
MI —— RH+MP	24.53	11.90	12.84	8.41	1.65	0.54	16	250	460	25160	4335	29955
MP —— RH+MI	27.27	14.17	16.50	11.12	2.91	0.92	18	163	307	14920	3160	18387
P=.05	2.37	1.88	1.65	1.24	0.45	0.17	4.43					660.39
P=.01	3.18	2.53	2.21	1.66	0.60	0.22	5.94					897.61

MI = Meloidogyne incognita; MP = Macrophomina phaseolina; RH = Rhizobium;
+ = Simultaneous inoculation; —— = inoculation followed by 10 days later.

Appendix - IV Response of 65 chickpea varieties against M. incognita and M. phaseolina.

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
	C	30.70	21.47	8.98	7.48	1.92	0.84	10	-	-	-	-	-
Gora Hissar	MI	16.70	12.90	4.76	5.14	0.89	0.41	4	320	781	38370	7835	46986
	MP	27.10	18.77	7.28	5.99	1.26	0.58	6	-	-	-	-	-
	P=.05	1.66	1.00	0.67	0.71	0.08	0.07	2.72					
	P=.01	2.75	1.66	1.11	1.17	0.13	0.11	4.52					
	C	37.63	20.27	9.06	11.68	2.83	1.29	22	-	-	-	-	-
L-144	MI	27.93	15.00	6.83	9.25	1.92	0.91	13	125	215	18860	3330	22405
	MP	32.23	17.87	7.35	10.44	2.32	1.09	16	-	-	-	-	-
	P=.05	0.76	1.14	0.51	0.98	0.19	0.11	2.00					
	P=.01	1.27	1.88	0.84	1.62	0.31	0.18	3.32					
	C	37.87	17.50	7.43	6.85	1.75	0.92	24	-	-	-	-	-
Annegiri	MI	28.57	13.83	5.02	4.78	1.17	0.60	14	174	284	17370	2950	20604
	MP	30.33	15.73	5.62	5.66	1.48	0.79	19	-	-	-	-	-
	P=.05	1.60	1.80	0.50	0.25	0.12	0.04	7.23					
	P=.01	2.66	2.98	0.83	0.42	0.20	0.07	11.99					
	C	27.76	23.46	8.37	10.34	1.71	1.08	12	-	-	-	-	-
Avrodhi	MI	20.27	16.40	5.53	8.28	1.09	0.77	7	290	660	29450	6320	36430
	MP	23.00	18.47	6.69	9.06	1.25	0.88	7	-	-	-	-	-
	P=.05	0.43	1.59	0.60	0.38	0.22	0.09	5.21					
	P=.01	0.71	2.63	1.00	0.62	0.36	0.15	8.64					
	C	32.80	17.27	9.87	7.69	1.84	0.99	22	-	-	-	-	-
C-235	MI	29.30	15.16	8.19	7.10	1.48	0.81	14	86	103	6765	1318	8186
	MP	27.10	14.13	7.73	6.49	1.34	0.70	15	-	-	-	-	-
	P=.05	1.69	1.51	0.52	0.53	0.23	0.11	4.78					
	P=.01	2.80	2.49	0.83	0.87	0.38	0.18	7.92					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
BGM-417	C	35.70	23.80	9.88	9.49	1.98	1.28	26	-	-	-	-	-
	MI	31.77	20.67	8.94	8.46	1.64	1.06	16	78	112	8412	1510	10034
	MP	30.17	19.20	8.18	7.79	1.45	0.91	18	-	-	-	-	-
	P=.05	1.22	0.79	0.63	0.44	0.09	0.12	4.44					
	P=.01	2.02	1.31	1.04	0.73	0.14	0.20	7.36					
K-850	C	37.53	19.60	13.82	12.64	2.62	1.23	34	-	-	-	-	-
	MI	33.30	17.20	11.44	11.09	1.95	0.89	19	108	205	13520	2640	16365
	MP	30.97	15.13	9.70	9.46	1.67	0.86	22	-	-	-	-	-
	P=.05	1.50	0.24	0.91	0.67	0.24	0.03	5.47					
	P=.01	2.48	0.40	1.51	1.10	0.40	0.05	9.08					
JG-315	C	35.53	22.13	14.16	12.83	1.87	1.29	18	-	-	-	-	-
	MI	27.30	16.20	10.93	9.04	1.29	0.91	10	156	260	17390	2330	19980
	MP	30.90	17.67	11.99	10.11	1.58	1.11	13	-	-	-	-	-
	P=.05	1.13	0.36	0.63	0.36	0.06	0.10	1.31					
	P=.01	1.88	0.59	1.04	0.60	0.11	0.16	2.17					
GNG-146	C	41.33	21.73	14.89	10.83	2.24	1.17	60	-	-	-	-	-
	MI	29.83	15.53	10.42	8.19	1.41	0.77	36	182	308	20130	2780	23218
	MP	34.23	18.20	11.58	8.81	1.62	0.89	40	-	-	-	-	-
	P=.05	1.41	1.33	0.37	0.62	0.18	0.08	13.09					
	P=.01	2.34	2.21	0.61	1.02	0.30	0.13	21.70					
Gaurav	C	34.20	19.03	9.76	9.56	1.62	0.91	20	-	-	-	-	-
	MI	29.80	16.63	7.55	8.05	1.18	0.72	10	118	229	13695	2120	16044
	MP	26.57	15.23	6.41	7.13	1.05	0.68	14	-	-	-	-	-
	P=.05	1.78	1.22	0.82	0.38	0.12	0.11	6.97					
	P=.01	2.95	2.02	1.36	0.62	0.20	0.17	11.55					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root	ules		Females	Eggs	Larvae	Total
ICC-7002	C	44.70	19.43	10.05	8.00	1.82	0.95	36	-	-	-	-	-
	MI	34.60	14.90	7.19	5.68	1.22	0.65	19	164	318	18475	2560	21353
	MP	37.53	16.13	7.62	6.22	1.36	0.71	24	-	-	-	-	-
	P=.05	0.50	1.23	0.31	0.28	0.09	0.07	7.74					
	P=.01	0.82	2.05	0.51	0.47	0.15	0.12	12.84					
BG-244	C	38.93	26.70	10.86	10.41	1.83	1.15	21	-	-	-	-	-
	MI	30.17	20.20	6.88	7.29	1.16	0.71	12	241	405	24270	4260	28935
	MP	33.13	22.37	8.15	9.05	1.41	0.89	16	-	-	-	-	-
	P=.05	2.03	1.51	0.84	0.51	0.10	0.07	4.81					
	P=.01	3.36	2.51	1.39	0.83	0.16	0.12	7.97					
H81-73	C	40.83	32.67	15.17	14.06	2.89	1.39	70	-	-	-	-	-
	MI	30.30	23.93	12.19	11.83	1.91	0.92	41	180	312	19350	2935	22597
	MP	28.60	21.20	11.56	10.30	1.69	0.78	45	-	-	-	-	-
	P=.05	1.33	1.78	0.45	0.32	0.15	0.06	9.66					
	P=.01	2.21	2.94	0.75	0.52	0.24	0.11	16.02					
BGM-408	C	47.33	34.63	19.44	13.35	3.27	1.56	36	-	-	-	-	-
	MI	32.70	25.26	13.94	9.08	1.99	0.98	22	262	502	27120	4870	32492
	MP	40.20	29.53	15.57	10.64	2.63	1.31	30	-	-	-	-	-
	P=.05	1.10	1.17	0.84	0.62	0.23	0.09	1.51					
	P=.01	1.82	1.93	1.39	1.02	0.38	0.15	2.51					
P-256	C	48.50	22.67	28.54	19.92	6.08	1.84	37	-	-	-	-	-
	MI	35.40	15.67	19.58	13.86	3.52	1.14	19	297	736	34218	6955	41909
	MP	37.30	16.37	20.31	14.39	3.60	1.18	23	-	-	-	-	-
	P=.05	1.96	1.01	1.89	1.20	0.34	0.18	6.78					
	P=.01	3.24	1.68	3.14	1.99	0.56	0.31	11.24					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4918	C	58.03	26.33	41.19	17.65	8.40	1.80	106	-	-	-	-	-
	MI	44.03	19.86	30.16	13.23	5.69	1.19	69	156	326	24370	2870	27566
	MP	50.73	23.56	35.26	15.32	7.12	1.49	83	-	-	-	-	-
	P=.05	2.76	1.13	2.30	1.33	0.90	0.31	4.53					
	P=.01	4.58	1.88	3.81	2.20	1.49	0.51	7.52					
IC-4919	C	51.06	24.53	43.31	19.03	8.85	1.34	152	-	-	-	-	-
	MI	43.40	21.13	37.50	16.37	7.31	1.13	129	53	112	9140	1250	10502
	MP	46.26	22.50	38.93	16.69	7.64	1.20	135	-	-	-	-	-
	P=.05	2.86	2.54	2.65	0.95	0.77	0.10	19.68					
	P=.01	4.75	4.22	4.39	1.57	1.27	0.17	32.65					
IC-4920	C	59.13	26.66	45.75	13.73	6.73	1.85	135	-	-	-	-	-
	MI	37.83	18.43	29.23	8.97	5.41	1.27	77	236	387	27115	3315	30817
	MP	46.73	22.03	32.53	10.72	6.25	1.41	90	-	-	-	-	-
	P=.05	2.08	1.19	0.66	1.45	0.28	0.22	18.20					
	P=.01	3.45	1.98	1.10	2.41	0.47	0.36	30.18					
IC-4921	C	51.80	23.66	60.24	19.40	10.51	1.74	107	-	-	-	-	-
	MI	45.46	20.70	53.10	16.74	8.49	1.43	72	60	108	7240	935	8283
	MP	45.20	22.40	52.56	17.15	8.56	1.32	84	-	-	-	-	-
	P=.05	2.25	0.73	2.43	1.08	0.96	0.16	18.25					
	P=.01	3.73	1.21	4.04	1.78	1.59	0.26	30.27					
IC-4922	C	54.40	26.33	60.00	16.53	10.50	2.10	91	-	-	-	-	-
	MI	43.30	20.53	44.12	11.74	7.10	1.50	56	157	296	19350	2730	22376
	MP	48.36	22.03	51.53	13.51	8.72	1.64	72	-	-	-	-	-
	P=.05	1.33	1.81	2.43	1.23	1.09	0.19	4.81					
	P=.01	2.21	3.00	4.04	2.04	1.81	0.31	4.97					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4923	C	65.73	29.16	66.06	16.56	12.27	1.73	109	-	-	-	-	-
	MI	56.50	24.56	56.63	13.66	9.90	1.39	78	81	130	10040	1236	11406
	MP	58.36	25.53	58.66	14.20	10.54	1.47	92	-	-	-	-	-
	P=.05	2.48	1.00	2.16	1.17	0.66	0.14	9.10					
	P=.01	4.11	1.66	3.58	1.95	1.00	0.24	15.09					
IC-4924	C	48.50	22.63	61.50	13.10	6.90	1.38	64	-	-	-	-	-
	MI	41.50	18.93	51.16	10.58	5.67	1.19	48	66	124	9780	1315	11219
	MP	39.50	17.80	48.96	9.72	5.16	0.94	44	-	-	-	-	-
	P=.05	3.85	0.97	1.85	1.63	0.49	0.27	12.64					
	P=.01	6.38	1.61	3.06	2.71	0.82	0.44	20.97					
IC-4925	C	44.20	22.80	46.74	12.73	10.02	1.80	103	-	-	-	-	-
	MI	34.73	17.16	32.03	9.37	6.61	1.21	60	160	318	24964	2840	28122
	MP	36.43	18.63	36.10	10.05	7.94	1.34	83	-	-	-	-	-
	P=.05	2.36	1.71	2.67	0.76	0.73	0.11	12.63					
	P=.01	3.91	2.83	4.42	1.25	1.21	0.19	20.95					
IC-4926	C	57.10	27.80	34.53	13.83	6.72	1.21	96	-	-	-	-	-
	MI	50.76	23.26	29.30	12.19	5.60	1.06	70	52	118	8750	1060	9928
	MP	40.96	21.46	26.23	10.64	4.87	0.92	66	-	-	-	-	-
	P=.05	2.19	0.38	1.61	0.66	0.06	0.04	11.07					
	P=.01	3.63	0.63	2.67	1.10	0.09	0.07	18.35					
IC-4927	C	55.50	29.36	28.98	16.40	6.87	1.38	109	-	-	-	-	-
	MI	46.23	25.13	22.76	13.04	5.13	1.02	59	138	226	16475	1835	18536
	MP	48.56	24.96	24.13	13.91	5.77	1.11	87	-	-	-	-	-
	P=.05	1.50	1.49	1.42	2.13	0.77	0.11	6.07					
	P=.01	2.48	2.47	2.35	3.52	1.27	0.18	10.06					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm) Shoot	Length (cm) Root	Fresh wt.(gm) Shoot	Fresh wt.(gm) Root	Dry wt.(gm) Shoot	Dry wt.(gm) Root	Nodules	Galls	Nematode population Females	Nematode population Eggs	Nematode population Larvae	Nematode population Total
IC-4928	C	43.36	26.40	41.25	22.13	9.84	2.12	86	-	-	-	-	-
	MI	33.53	19.86	32.16	17.43	7.30	1.64	47	120	234	16160	2070	18464
	MP	38.33	23.33	36.43	19.08	8.57	1.82	75	-	-	-	-	-
	P=.05	1.41	1.77	1.75	1.45	0.56	0.13	15.53					
	P=.01	2.33	2.93	2.91	2.40	0.92	0.22	25.76					
IC-4929	C	46.76	24.86	46.28	19.36	8.46	1.77	61	-	-	-	-	-
	MI	37.83	19.46	36.83	15.12	6.30	1.38	32	114	208	14970	1740	16918
	MP	41.13	21.90	39.33	17.16	7.05	1.52	47	-	-	-	-	-
	P=.05	2.49	1.58	1.70	2.45	0.96	0.12	4.41					
	P=.01	4.14	2.62	2.83	4.07	1.60	0.19	7.31					
IC-4930	C	51.53	22.86	38.33	12.96	8.96	1.41	70	-	-	-	-	-
	MI	45.66	19.56	32.26	10.78	7.15	1.10	50	91	192	11145	1585	12922
	MP	40.96	16.83	27.16	9.46	5.88	0.94	44	-	-	-	-	-
	P=.05	1.71	1.56	2.65	1.45	1.26	0.13	16.94					
	P=.01	2.83	2.58	4.40	2.40	2.10	0.21	28.09					
IC-4931	C	55.56	25.46	45.71	23.00	12.18	1.92	92	-	-	-	-	-
	MI	46.39	21.43	35.50	17.89	9.12	1.40	54	135	271	19322	2418	22011
	MP	45.80	20.03	34.86	16.32	8.22	1.26	63	-	-	-	-	-
	P=.05	2.09	2.51	2.72	1.30	1.41	0.33	15.97					
	P=.01	3.46	4.17	4.51	2.15	2.35	0.55	26.49					
IC-4932	C	53.16	24.26	56.25	18.70	12.54	1.81	50	-	-	-	-	-
	MI	48.20	22.26	49.41	16.75	10.53	1.58	34	42	95	8180	1140	9415
	MP	45.56	20.50	45.90	15.54	9.76	1.31	37	-	-	-	-	-
	P=.05	2.35	2.25	1.73	1.65	0.63	0.25	12.84					
	P=.01	3.90	3.74	2.86	2.74	1.05	0.42	21.30					

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Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4933	C	57.60	25.50	48.23	15.96	9.55	1.59	114	-	-	-	-	-
	MI	43.76	18.86	32.76	11.84	5.85	1.02	62	211	402	30265	3735	34402
	MP	52.50	22.83	41.93	13.73	7.85	1.27	94	-	-	-	-	-
	P=.05	4.58	1.97	2.29	3.65	0.49	0.23	5.32					
	P=.01	7.59	3.27	3.80	6.06	0.81	0.38	8.82					
IC-4934	C	49.93	20.03	31.40	17.66	8.60	1.22	73	-	-	-	-	-
	MI	39.76	16.23	24.13	13.85	6.30	0.89	48	122	249	17220	1870	19339
	MP	43.23	18.16	27.15	15.42	7.19	0.97	61	-	-	-	-	-
	P=.05	4.19	1.45	2.28	1.64	0.76	0.11	11.95					
	P=.01	6.94	2.41	3.78	2.71	1.26	0.18	19.81					
IC-4935	C	42.00	24.43	21.43	13.33	8.73	1.63	78	-	-	-	-	-
	MI	31.13	16.86	13.96	9.10	5.63	0.98	42	205	386	28415	3118	31919
	MP	37.26	21.06	17.26	11.19	6.86	1.31	53	-	-	-	-	-
	P=.05	2.71	1.48	1.94	1.41	0.78	0.26	12.75					
	P=.01	4.50	2.45	3.22	2.34	1.29	0.43	21.15					
IC-4937	C	71.73	36.50	56.94	33.33	14.04	2.23	103	-	-	-	-	-
	MI	62.10	31.06	48.33	28.64	11.45	1.83	79	41	86	6970	1030	8086
	MP	63.70	32.03	50.23	29.13	11.64	1.82	84	-	-	-	-	-
	P=.05	3.79	0.88	1.65	2.36	0.20	0.32	18.87					
	P=.01	6.28	1.46	2.74	3.91	0.33	0.53	31.30					
IC-4938	C	58.83	29.06	47.56	17.46	8.60	1.69	356	-	-	-	-	-
	MI	50.26	25.36	40.10	14.91	6.97	1.39	243	50	117	9350	980	10447
	MP	51.70	26.16	42.13	15.17	7.42	1.49	308	-	-	-	-	-
	P=.05	0.83	1.57	3.35	1.77	0.99	0.07	55.42					
	P=.01	1.37	2.60	5.56	2.93	1.64	0.12	91.91					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4939	C	30.47	21.13	8.41	4.39	1.68	0.63	37	-	-	-	-	-
	MI	25.60	17.20	6.82	3.67	1.22	0.47	18	106	172	22375	1365	23912
	MP	27.43	18.60	6.40	3.80	1.37	0.53	23	-	-	-	-	-
	P=.05	4.34	1.99	0.54	0.84	0.22	0.13	7.74					
	P=.01	7.19	3.30	0.89	1.40	0.37	0.21	12.84					
IC-4940	C	37.83	21.70	13.68	5.62	2.74	0.80	26	-	-	-	-	-
	MI	34.10	19.17	11.69	4.95	2.30	0.68	20	66	114	11320	965	12399
	MP	33.17	18.93	11.60	4.83	2.24	0.65	18	-	-	-	-	-
	P=.05	3.39	1.86	0.63	1.12	0.21	0.07	9.75					
	P=.01	5.62	3.09	1.04	1.86	0.34	0.12	16.17					
IC-4941	C	31.20	19.07	14.71	4.93	2.94	0.69	81	-	-	-	-	-
	MI	27.40	16.57	12.25	4.14	2.41	0.56	50	41	76	9670	774	10520
	MP	28.17	16.90	12.47	4.30	2.44	0.58	59	-	-	-	-	-
	P=.05	2.12	3.45	1.30	1.02	0.39	0.12	14.62					
	P=.01	3.51	5.72	2.16	1.69	0.65	0.19	24.25					
IC-4942	C	24.00	18.40	10.40	4.90	2.08	0.70	34	-	-	-	-	-
	MI	21.03	16.73	9.17	4.12	1.76	0.57	21	39	66	8315	635	9016
	MP	22.67	17.06	9.46	4.30	1.80	0.59	30	-	-	-	-	-
	P=.05	3.84	2.86	1.41	1.09	0.20	0.09	10.47					
	P=.01	6.36	4.74	2.34	1.81	0.33	0.14	17.36					
IC-4943	C	39.43	18.60	14.64	6.64	2.93	0.95	42	-	-	-	-	-
	MI	31.90	15.33	11.47	4.95	2.29	0.68	26	92	156	11360	1490	13006
	MP	34.67	16.77	12.57	5.43	2.44	0.75	31	-	-	-	-	-
	P=.05	3.48	2.77	2.42	1.65	0.62	0.02	12.78					
	P=.01	5.77	5.60	4.01	2.73	1.02	0.04	20.36					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4944	C	34.47	16.63	15.99	7.13	3.20	1.02	37	-	-	-	-	-
	MI	30.10	14.47	13.95	6.75	2.76	0.83	32	29	60	6690	775	7525
	MP	28.60	13.77	11.70	5.23	2.40	0.77	29	-	-	-	-	-
	P=.05	3.70	1.98	1.34	0.56	0.46	0.18	3.07					
	P=.01	6.13	3.29	2.21	0.92	0.75	0.30	5.09					
IC-4945	C	34.50	18.50	9.27	4.62	1.85	0.66	48	-	-	-	-	-
	MI	30.23	16.13	8.07	3.90	1.48	0.55	34	39	62	8960	690	9712
	MP	28.83	15.23	7.68	3.17	1.36	0.49	32	-	-	-	-	-
	P=.05	3.62	3.75	0.44	0.84	0.21	0.15	7.96					
	P=.01	6.00	6.22	0.72	1.40	0.34	0.25	13.20					
IC-4946	C	41.10	17.57	14.90	6.68	2.98	0.95	26	-	-	-	-	-
	MI	36.83	14.13	12.51	5.87	2.41	0.76	18	48	77	8115	840	9032
	MP	36.03	14.03	12.47	5.70	2.48	0.78	19	-	-	-	-	-
	P=.05	1.33	3.70	1.45	0.60	0.26	0.35	5.68					
	P=.01	2.20	6.14	2.40	1.00	0.42	0.57	9.42					
IC-4947	C	32.13	26.27	21.94	9.26	4.18	1.32	39	-	-	-	-	-
	MI	26.27	21.60	17.75	7.50	3.42	0.96	28	96	136	11720	1254	13110
	MP	28.30	22.97	18.17	7.97	3.51	1.01	30	-	-	-	-	-
	P=.05	5.48	4.05	2.24	1.09	0.56	0.07	6.97					
	P=.01	9.09	6.72	3.71	1.68	0.93	0.12	11.55					
IC-4948	C	32.60	20.63	9.29	4.17	1.86	0.60	28	-	-	-	-	-
	MI	28.70	17.50	8.75	3.77	1.52	0.52	20	42	73	8170	790	9033
	MP	27.00	16.37	8.16	3.23	1.50	0.50	18	-	-	-	-	-
	P=.05	3.70	1.32	1.17	1.16	0.40	0.16	9.97					
	P=.01	6.14	2.20	1.93	1.92	0.67	0.26	16.53					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4949	C	27.87	18.47	9.35	4.96	1.87	0.71	28	-	-	-	-	-
	MI	22.40	15.10	7.39	4.08	1.32	0.51	17	104	170	15990	1460	17620
	MP	24.67	15.67	7.70	4.33	1.34	0.56	18	-	-	-	-	-
	P=.05	3.25	2.85	1.21	1.01	0.45	0.18	5.32					
	P=.01	5.39	4.73	2.01	1.67	0.75	0.31	8.82					
IC-4950	C	32.67	20.47	8.79	4.28	1.76	0.61	20	-	-	-	-	-
	MI	25.87	15.90	6.85	3.36	1.35	0.44	12	96	158	10750	1735	12643
	MP	27.10	17.73	7.80	3.78	1.52	0.49	18	-	-	-	-	-
	P=.05	1.74	2.09	1.12	1.15	0.47	0.12	6.41					
	P=.01	2.88	3.46	1.86	1.91	0.78	0.21	10.63					
IC-4951	C	35.63	21.20	10.14	4.78	2.03	0.68	44	-	-	-	-	-
	MI	31.47	18.17	8.49	3.96	1.66	0.55	30	84	123	12030	1360	13513
	MP	32.90	18.67	8.70	4.20	1.80	0.57	37	-	-	-	-	-
	P=.05	2.12	3.21	1.86	1.21	0.34	0.03	10.86					
	P=.01	3.51	5.32	3.09	2.01	0.56	0.05	18.01					
IC-4952	C	30.30	21.17	8.81	4.19	1.76	0.60	47	-	-	-	-	-
	MI	26.20	18.27	7.57	3.84	1.46	0.49	36	58	97	9070	945	9112
	MP	23.23	15.67	6.30	3.05	1.28	0.46	31	-	-	-	-	-
	P=.05	2.52	1.59	0.77	1.11	0.13	0.10	12.55					
	P=.01	4.18	2.64	1.28	1.83	0.21	0.17	20.82					
IC-4953	C	34.80	19.33	10.67	5.02	2.13	0.72	69	-	-	-	-	-
	MI	29.37	17.33	9.00	4.56	1.76	0.59	46	49	78	8620	670	9368
	MP	30.40	18.30	9.13	4.23	1.80	0.61	48	-	-	-	-	-
	P=.05	4.31	3.12	1.91	0.46	0.50	0.30	1012					
	P=.01	7.15	5.17	3.17	0.77	0.83	0.49	16.79					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4954	C	29.27	24.47	10.90	4.77	2.18	0.68	26	-	-	-	-	-
	MI	25.50	19.27	8.19	4.08	1.78	0.55	16	57	87	9615	915	10617
	MP	23.93	17.77	7.70	3.47	1.62	0.51	18	-	-	-	-	-
	P=.05	2.38	3.50	1.58	0.79	0.54	0.13	6.04					
	P=.01	3.95	5.80	2.62	1.31	0.89	0.21	10.02					
IC-4955	C	36.07	24.33	11.99	5.08	2.40	0.73	25	-	-	-	-	-
	MI	30.03	21.57	10.18	4.76	1.97	0.60	17	37	54	8970	718	9742
	MP	27.73	18.43	9.60	3.73	1.12	0.54	13	-	-	-	-	-
	P=.05	3.38	3.93	1.58	1.28	0.39	0.14	7.55					
	P=.01	5.61	6.51	2.63	2.12	0.64	0.23	12.53					
IC-4956	C	37.10	20.27	14.75	6.69	2.95	0.96	40	-	-	-	-	-
	MI	34.03	17.37	12.49	5.90	2.42	0.79	30	75	118	12660	975	13753
	MP	30.80	16.13	10.90	5.37	2.09	0.72	28	-	-	-	-	-
	P=.05	4.34	3.17	1.83	0.37	0.67	0.17	7.46					
	P=.01	7.19	5.25	3.03	0.62	1.11	0.28	12.37					
IC-4957	C	30.87	21.37	14.89	5.88	2.98	0.84	46	-	-	-	-	-
	MI	24.83	16.47	10.68	4.16	1.88	0.54	26	152	224	24920	1740	26884
	MP	24.20	16.17	10.40	4.07	1.83	0.51	31	-	-	-	-	-
	P=.05	2.32	2.98	1.70	0.54	0.44	0.19	4.81					
	P=.01	3.85	4.94	2.82	0.91	0.74	0.32	7.97					
IC-4958	C	32.33	18.43	9.72	3.92	1.94	0.56	17	-	-	-	-	-
	MI	27.53	15.63	8.25	3.05	1.58	0.45	13	65	107	11970	965	13042
	MP	30.60	17.57	8.80	3.27	1.62	0.47	11	-	-	-	-	-
	P=.05	4.16	0.59	1.09	0.89	0.54	0.11	4.21					
	P=.01	6.90	0.98	1.80	1.48	0.90	0.18	6.98					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
IC-4959	C	34.33	23.57	6.97	3.50	1.39	0.52	11	-	-	-	-	-
	MI	29.33	18.43	5.82	2.60	1.12	0.41	8	46	74	8230	940	9244
	MP	30.90	18.77	6.00	2.67	1.17	0.43	9	-	-	-	-	-
	P=.05	4.84	2.58	1.00	0.69	0.12	0.26	2.62					
	P=.01	8.03	4.29	1.66	1.14	0.19	0.44	4.34					
IC-4960	C	26.00	17.43	9.17	5.98	1.83	0.84	27	-	-	-	-	-
	MI	21.67	14.43	7.82	5.06	1.52	0.68	18	85	109	11615	1260	12984
	MP	22.10	15.17	8.15	5.27	1.55	0.70	20	-	-	-	-	-
	P=.05	4.24	2.41	1.45	0.83	0.46	0.20	8.10					
	P=.01	7.04	4.00	2.40	1.37	0.76	0.34	13.44					
IC-4961	C	36.13	20.77	9.30	3.76	1.86	0.52	23	-	-	-	-	-
	MI	30.43	17.50	8.10	3.26	1.51	0.43	14	33	40	8960	850	9856
	MP	32.97	17.80	8.63	3.37	1.54	0.44	18	-	-	-	-	-
	P=.05	4.88	2.90	0.77	0.41	0.45	0.17	6.84					
	P=.01	8.10	4.80	1.28	0.67	0.75	0.27	11.35					
IC-4962	C	36.10	23.30	8.70	4.12	1.74	0.59	32	-	-	-	-	-
	MI	31.80	21.06	7.70	3.92	1.40	0.44	20	65	98	10675	1110	11883
	MP	30.10	19.77	7.23	3.23	1.34	0.41	25	-	-	-	-	-
	P=.05	2.78	3.46	1.21	0.86	0.32	0.10	5.70					
	P=.01	4.61	5.73	2.02	1.43	0.53	0.17	9.49					
IC-4963	C	32.10	21.10	9.28	4.65	1.86	0.68	22	-	-	-	-	-
	MI	28.27	19.47	8.01	4.17	1.52	0.55	13	58	81	10115	1072	11268
	MP	26.53	18.17	7.53	3.83	1.36	0.49	14	-	-	-	-	-
	P=.05	4.27	3.36	1.48	0.88	0.37	0.13	3.21					
	P=.01	7.08	5.58	2.45	1.46	0.61	0.22	5.32					

Contd....

Appendix IV (Contd....)

Variety	Treatm.	Length (cm) Shoot	Length (cm) Root	Fresh wt.(gm) Shoot	Fresh wt.(gm) Root	Dry wt.(gm) Shoot	Dry wt.(gm) Root	Nodules	Galls	Nematode population Females	Nematode population Eggs	Nematode population Larvae	Nematode population Total
IC-4964	C	26.33	23.73	8.33	3.97	1.67	0.58	28	-	-	-	-	-
	MI	22.97	19.33	7.68	3.16	1.38	0.48	18	63	94	10670	1175	11939
	MP	20.63	18.20	7.23	2.93	1.35	0.46	19	-	-	-	-	-
	P=.05	3.05	4.15	0.68	0.75	0.37	0.10	4.72					
	P=.01	5.06	6.87	1.14	1.25	0.61	0.17	7.83					
IC-4965	C	35.43	22.23	8.70	4.22	1.74	0.60	23	-	-	-	-	-
	MI	31.03	21.20	7.42	3.65	1.46	0.50	16	79	120	11750	1625	13495
	MP	30.97	20.18	7.27	3.43	1.43	0.48	17	-	-	-	-	-
	P=.05	3.52	4.80	1.10	0.94	0.28	0.16	4.44					
	P=.01	5.83	7.97	1.83	1.56	0.46	0.26	7.36					
IC-4966	C	31.73	17.33	9.18	3.82	1.84	0.57	37	-	-	-	-	-
	MI	28.77	14.30	7.64	3.26	1.52	0.47	26	35	58	7620	1008	8686
	MP	27.10	13.87	7.10	3.17	1.36	0.43	23	-	-	-	-	-
	P=.05	2.74	3.22	2.96	0.39	0.30	0.13	6.59					
	P=.01	4.55	5.33	4.91	0.65	0.50	0.21	10.92					
IC-4967	C	34.10	17.53	11.03	4.96	2.21	0.72	32	-	-	-	-	-
	MI	29.13	16.37	9.06	4.37	1.70	0.54	19	98	167	12460	1235	13862
	MP	27.67	15.68	8.72	3.85	1.56	0.51	20	-	-	-	-	-
	P=.05	4.17	3.10	1.76	0.27	0.33	0.13	3.21					
	P=.01	6.91	5.15	2.92	0.44	0.55	0.22	5.32					
IC-4968	C	30.60	19.43	10.53	4.85	2.11	0.67	23	-	-	-	-	-
	MI	27.40	16.47	9.26	4.08	1.76	0.56	15	55	88	10350	1130	11568
	MP	28.67	16.80	9.47	4.17	1.73	0.55	17	-	-	-	-	-
	P=.05	3.80	2.86	2.05	1.21	0.45	0.03	6.25					
	P=.01	6.30	4.74	3.40	2.01	0.74	0.05	10.37					

C = Control; MI= Meloidogyne incognita; MP = Macrophomina phaseolina.

Appendix - V Effect of ascorbic acid and *P. lilacinus* on plant growth nodulation, disease development and nematode multiplication.

Treatment		Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
Control		48.77	22.90	32.34	23.00	6.93	2.14	42	-	-	-	-	-
MI		39.20	18.27	25.08	16.94	5.12	1.51	24	294	755	34750	7320	42825
MP		40.67	18.97	26.39	17.45	5.20	1.59	29	-	-	-	-	-
MI+MP		29.70	13.50	17.11	10.84	3.32	0.89	10	209	596	18760	5380	24736
Ascorbic acid													
MI	Seed	43.60	20.20	28.15	19.94	5.79	1.75	30	172	337	14765	4310	19412
MP	Treatment	43.77	20.57	27.74	19.11	5.62	1.70	32	-	-	-	-	-
MI+MP		35.17	17.30	20.98	13.90	4.45	1.24	18	139	272	10490	3150	13912
MI		41.93	19.37	27.51	18.74	5.56	1.65	27	205	436	24670	5140	30246
MP	Folior	42.75	19.47	27.07	18.08	5.45	1.63	29	-	-	-	-	-
MI+MP	spray	34.37	17.00	19.76	13.14	4.27	1.13	16	166	356	13850	2820	17026
MI	Soil doses	40.57	19.20	26.92	18.70	5.52	1.68	28	207	444	24490	5315	30249
MP	5 ml	41.37	18.97	26.89	18.02	5.40	1.65	31	-	-	-	-	-
MI+MP		33.13	16.17	19.24	13.32	4.07	1.12	17	162	336	13855	2668	16859
MI		42.27	20.13	28.19	19.04	5.73	1.85	31	170	352	14680	3370	18402
MP	10 ml	42.03	19.50	27.95	18.61	5.59	1.80	34	-	-	-	-	-
MI+MP		35.73	17.23	21.58	13.89	4.53	1.35	19	134	293	11740	2715	14748

Contd....

Appendix - V (Contd....)

Treatment		Length (cm) Shoot	Length (cm) Root	Fresh wt.(gm) Shoot	Fresh wt.(gm) Root	Dry wt.(gm) Shoot	Dry wt.(gm) Root	Nod-ules	Galls	Nematode population Females	Nematode population Eggs	Nematode population Larvae	Nematode population Total
MI		44.23	21.20	29.18	20.60	6.08	1.92	35	145	304	12130	3130	15564
MP	10 ml	43.03	20.83	28.67	19.12	5.87	1.82	34	-	-	-	-	-
MI+MP		36.83	18.87	23.47	14.95	4.90	1.50	22	88	174	6360	1270	7808
P. lilacinus													
MI		41.48	19.24	27.10	19.16	5.60	1.73	31	217	494	24225	5290	30009
MP	0.5 gm	41.05	19.41	27.17	18.22	5.36	1.64	32	-	-	-	-	-
MI+MP		33.70	16.56	19.40	13.75	4.12	1.22	17	148	367	11720	4820	16907
MI		43.36	20.24	29.46	20.36	6.10	1.94	35	142	352	14240	3820	18412
MP	1.0 gm	42.10	20.10	28.07	19.10	5.56	1.69	34	-	-	-	-	-
MI+MP		36.18	17.70	22.55	15.27	5.08	1.47	20	105	259	8190	2370	10819
MI		45.78	21.47	30.85	21.46	6.43	2.04	39	84	189	8470	1860	10519
MP	2.0 gm	42.46	20.92	28.42	19.95	5.87	1.78	37	-	-	-	-	-
MI+MP		39.40	19.18	25.17	17.48	5.72	1.70	23	62	148	5245	1036	6429
P=.05		2.49	1.90	2.21	1.73	0.38	0.27	5.00					723.90
P=.01		3.32	2.53	2.95	2.31	0.50	0.37	6.66					971.38

MI = Meloidogyne incognita; MP = Macrophomina phaseolina.

Appendix - VI Effect of biocontrol agents and plant extracts on plant growth, nodulation, disease development and nematode multiplication.

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
Control	50.57	23.17	32.28	23.21	7.73	2.28	44	-	-	-	-	-
MI	41.10	18.30	25.03	17.77	5.54	1.69	26	288	732	35060	6980	42272
MP	41.70	18.63	25.58	18.16	5.92	1.76	29	-	-	-	-	-
MI+MP	32.10	13.47	18.34	12.44	3.69	1.09	14	204	464	19815	5470	25779
C. citratus												
MI	43.20	19.47	26.16	18.48	6.08	1.77	31	217	604	29750	5425	35779
MP 5 ml	43.67	19.80	26.35	18.72	6.24	1.82	34	-	-	-	-	-
MI+MP	36.83	15.87	21.08	15.04	4.47	1.38	19	146	396	14430	3970	18796
MI	44.90	20.73	27.66	19.57	6.71	1.85	35	162	460	19280	3875	23615
MP 10 ml	45.20	20.83	27.96	20.01	6.82	1.93	37	-	-	-	-	-
MI+MP	39.10	17.33	24.92	16.97	5.45	1.57	24	97	272	9370	2340	11982
MI	47.43	21.50	28.94	21.13	7.07	1.94	35	123	286	11460	2710	14456
MP 20 ml	47.90	21.93	29.93	21.59	7.14	1.98	39	-	-	-	-	-
MI+MP	42.17	19.90	26.89	18.52	6.15	1.76	26	68	144	6790	1680	8614
P=.05	2.36	2.27	2.34	2.04	0.80	0.27	5.28					572.07
P=.01	3.20	3.08	3.17	2.76	1.09	0.36	8.52					793.96
E. crassipes												
MI	42.73	19.17	26.72	18.90	6.02	1.73	28	234	622	29890	5730	36242
MP 5 ml	43.10	19.73	27.05	19.29	6.29	1.81	32	-	-	-	-	-
MI+MP	36.13	15.47	20.15	15.04	4.43	1.36	17	165	416	14510	4640	19566

Cont....

Appendix - VI (Contd....)

Treatment		Length (cm) Shoot	Length (cm) Root	Fresh wt.(gm) Shoot	Fresh wt.(gm) Root	Dry wt.(gm) Shoot	Dry wt.(gm) Root	Nod-ules	Galls	Nematode population Females	Nematode population Eggs	Nematode population Larvae	Nematode population Total
MI		44.23	20.13	27.09	19.99	6.54	1.84	30	187	520	21430	4260	26210
MP	10 ml	44.73	20.83	27.38	19.74	6.70	1.89	34	-	-	-	-	-
MI+MP		38.50	16.87	22.31	16.81	5.27	1.57	20	120	308	10430	2860	13598
MI		47.36	20.87	28.68	20.72	7.03	1.93	34	142	350	13620	3280	17250
MP	20 ml	47.86	21.30	28.25	20.80	7.16	1.95	35	-	-	-	-	-
MI+MP		41.27	19.47	25.22	18.84	6.02	1.72	23	90	186	7925	2040	10151
P=.05		2.07	1.71	3.16	2.06	0.82	0.26	5.23					955.21
P=.01		2.81	2.32	4.28	2.79	1.11	0.36	7.08					1325.71
I. carnea													
MI		42.23	18.80	26.49	18.47	5.98	1.82	29	243	652	31875	5615	38142
MP	5 ml	42.70	18.87	26.37	18.47	6.05	1.82	32	-	-	-	-	-
MI+MP		35.97	15.37	20.03	14.73	4.41	1.36	16	177	470	16470	4930	21870
MI		43.77	19.83	27.22	19.75	6.37	1.87	34	198	490	22630	4710	27830
MP	10 ml	43.03	19.50	26.93	19.40	6.28	1.86	34	-	-	-	-	-
MI+MP		38.47	16.90	22.29	16.43	5.16	1.50	19	137	340	12160	3235	15735
MI		47.23	21.57	28.26	20.14	6.72	1.98	36	159	382	15240	3640	19262
MP	20 ml	46.67	21.23	27.91	19.90	6.57	1.94	34	-	-	-	-	-
MI+MP		41.17	18.10	24.34	18.44	5.91	1.65	21	108	216	9365	2660	12241
P=.05		1.81	1.72	1.98	2.36	0.75	0.26	5.70					1235.28
P=.01		2.45	2.33	2.69	3.19	1.01	0.35	7.73					1714.42

Cont....

Appendix - VI (Contd....)

Treatment		Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
P. lilacinus													
MI		43.48	20.09	26.78	19.22	6.15	1.86	31	220	602	24460	5420	30502
MP	0.50 gm	42.67	20.06	26.49	19.36	5.97	1.84	31	-	-	-	-	-
MI+MP		37.67	16.91	22.23	15.19	4.51	1.42	20	151	376	11690	4740	16806
MI		46.00	20.81	28.55	20.78	6.79	1.97	35	148	359	14460	3717	18536
MP	1.0 gm	43.79	20.32	27.36	19.82	6.18	1.93	33	-	-	-	-	-
MI+MP		39.61	18.60	24.67	17.82	5.67	1.64	24	103	262	8370	2460	11092
MI		47.37	21.63	30.14	21.89	7.20	2.04	39	81	206	8615	1950	10771
MP	2.0 gm	45.92	20.92	28.80	20.40	6.78	1.97	34	-	-	-	-	-
MI+MP		43.25	20.11	27.51	19.60	6.38	1.82	27	66	163	6120	1148	7431
P=.05		2.95	2.36	1.97	2.30	0.84	0.20	6.42					773.14
P=.01		3.99	3.20	2.67	3.11	1.12	0.27	8.70					1073.02
A. fusispora													
MI		43.30	19.77	26.91	18.85	5.84	1.83	31	223	430	27670	5340	34440
MP	5 gm	42.13	19.03	26.16	18.40	6.13	1.85	33	-	-	-	-	-
MI+MP		35.43	15.40	19.79	14.04	4.10	1.37	17	156	290	13670	3960	17920
MI		45.50	21.00	27.30	19.21	6.43	1.89	34	170	320	20240	4170	24730
MP	10 gm	43.60	20.27	26.67	18.60	6.27	1.87	35	-	-	-	-	-
MI+MP		38.30	16.53	22.88	16.16	4.70	1.45	20	116	228	9750	3050	13028

Coontd....

Appendix - VI (Contd....)

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
MI	46.20	21.77	28.90	20.04	6.79	1.98	38	132	260	12410	3290	15960
MP 20 gm	44.97	21.07	27.10	19.17	6.43	1.94	35	-	-	-	-	-
MI+MP	40.67	18.40	24.21	17.78	5.47	1.52	26	98	172	7310	2475	9957
P=.05	2.49	1.02	2.41	1.85	0.87	0.31	6.06					847.15
P=.01	3.37	1.38	3.26	2.51	1.18	0.42	4.22					1175.74
A. faecalis												
MI	40.47	17.80	23.75	16.08	5.20	1.61	24	258	524	32130	6110	38764
MP 5 ml	40.63	17.90	24.52	16.29	5.47	1.72	26	-	-	-	-	-
MI+MP	31.07	13.14	17.65	11.82	3.53	1.02	10	174	361	14460	4720	20011
MI	39.57	17.27	22.24	15.08	4.91	1.56	24	210	407	24460	5360	30227
MP 10 ml	39.77	17.23	22.28	15.15	5.14	1.67	23	-	-	-	-	-
MI+MP	30.77	12.85	17.02	11.36	3.44	0.97	10	146	295	11390	3980	15665
MI	38.47	16.56	21.15	14.59	4.55	1.49	19	165	338	18765	4290	23393
MP 20 ml	38.83	16.97	21.57	14.48	4.74	1.58	21	-	-	-	-	-
MI+MP	28.93	12.52	16.93	10.97	3.18	0.93	8	118	242	9715	3240	13197
P=.05	3.54	1.83	2.43	1.95	1.00	0.62	5.15					738.72
P=.01	4.80	2.49	3.29	2.64	1.36	0.84	6.98					1025.25
B. licheniformis												
MI	43.20	19.03	26.27	18.60	5.82	1.81	29	249	472	30400	5780	36652
MP 5 ml	42.00	19.17	26.33	18.86	6.07	1.86	31	-	-	-	-	-
MI+MP	34.33	14.80	19.16	14.35	4.22	1.35	18	162	332	15130	4315	19777

Contd....

Appendix - VI (Contd....)

Treatment		Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
		Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
MI		44.27	19.63	27.94	19.84	6.44	1.87	30	195	376	21820	4610	26806
MP	10 ml	42.60	19.43	27.38	19.61	6.21	1.90	32	-	-	-	-	-
MI+MP		36.33	17.12	21.17	15.97	4.59	1.42	20	124	260	10260	3480	14000
MI		46.63	20.73	28.52	20.92	7.08	1.98	36	156	305	15903	3720	19955
MP	20 ml	44.77	20.20	27.49	20.55	6.58	1.93	34	-	-	-	-	-
MI+MP		39.83	18.97	23.88	17.08	5.32	1.50	24	107	217	8640	2910	11764
P=.05		2.41	1.56	1.92	1.97	0.95	0.36	7.14					586.13
P=.01		3.27	2.11	2.60	2.66	1.29	0.45	9.68					813.48
P=.05		2.39	1.69	2.20	1.97	0.82	0.30	5.41					754.94
P=.01		3.14	2.22	2.89	2.59	1.07	0.40	7.11					1000.13

MI= Meloidogyne incognita; MP = Macrophomina phaseolina.

Appendix - VII Effect of culture filtrates of some common soil fungi on plant growth, nodulation, disease development and nematode multiplication.

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
Control	46.83	22.63	27.90	19.34	5.60	1.86	38	-	-	-	-	-
MI	39.33	18.40	22.76	15.20	4.14	1.41	21	296	780	37360	7215	45355
MP	39.77	18.60	23.17	15.50	4.28	1.45	25	-	-	-	-	-
MI+MP	31.20	14.37	16.47	10.78	2.59	0.91	15	211	565	20340	5620	26514
A. niger												
MI	41.73	20.30	23.84	16.33	4.65	1.56	26	166	309	24360	4370	29039
MP S/10	41.93	20.53	24.02	16.56	4.67	1.59	30	-	-	-	-	-
MI+MP	35.70	17.43	19.47	12.53	3.49	1.26	18	128	202	11215	3120	14537
MI	44.03	21.80	26.17	17.78	4.96	1.62	31	132	224	15780	2920	18924
MP S	44.63	21.50	26.29	17.90	4.92	1.76	34	-	-	-	-	-
MI+MP	39.73	19.97	22.84	14.18	4.28	1.46	23	77	176	8015	1780	9971
P=.05	1.94	1.64	2.12	1.99	0.35	0.24	7.44					579.69
P=.01	2.66	2.25	2.90	2.72	0.46	0.32	10.19					824.53
A. flavus												
MI	40.50	20.10	23.38	16.24	4.47	1.53	26	179	322	25730	4625	30677
MP S/10	40.73	20.77	23.64	16.54	4.50	1.56	27	-	-	-	-	-
MI+MP	34.20	17.23	18.87	12.29	3.37	1.22	17	140	245	12890	3405	16540

Contd....

Appendix - VII (Contd....)

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
MI	43.87	21.43	25.64	17.21	4.76	1.58	30	147	264	17145	3115	20524
MP S	44.27	21.30	25.55	17.44	4.85	1.62	32	-	-	-	-	-
MI+MP	38.77	19.83	22.21	13.86	4.16	1.39	19	86	195	9470	1865	11530
P=.05	1.75	1.17	2.30	2.47	0.58	0.16	8.02					642.21
P=.01	2.39	1.60	3.15	3.38	0.79	0.21	10.99					913.45
A. brassicicola												
MI	40.10	19.73	23.40	16.08	4.38	1.49	27	195	360	27175	4680	32215
MP S/10	40.30	19.20	23.60	16.28	4.45	1.50	29	-	-	-	-	-
MI+MP	34.73	15.97	17.98	12.80	3.22	1.16	16	156	261	14760	3495	18516
MI	43.17	20.30	24.75	16.64	4.69	1.57	28	166	280	18630	3330	22240
MP S	42.80	20.13	24.40	16.69	4.58	1.54	30	-	-	-	-	-
MI+MP	37.10	18.23	21.07	13.51	4.01	1.30	19	102	217	9925	1920	12062
P=.05	2.04	1.71	2.00	2.26	0.54	0.27	8.09					538.30
P=.01	2.80	2.34	2.74	3.10	0.74	0.37	11.08					765.65
A. triticina												
MI	40.87	18.90	23.87	15.70	4.31	1.47	24	228	417	29785	5170	35372
MP S/10	40.60	19.10	23.82	15.91	4.40	1.51	26	-	-	-	-	-
MI+MP	34.47	16.27	18.24	12.36	3.20	1.10	18	170	340	17310	3810	21460
MI	41.93	19.77	24.97	16.09	4.64	1.54	28	178	307	21670	3840	25787
MP S	42.20	19.87	24.20	16.18	4.51	1.57	30	-	-	-	-	-
MI+MP	36.50	17.67	20.80	12.98	3.82	1.31	21	130	256	11390	2330	13976
P=.05	2.12	1.20	2.06	2.43	0.45	0.16	7.56					751.70
P=.01	2.91	1.65	2.82	3.33	0.62	0.22	10.36					1069.19

Appendix - VII (Contd....)

Treatment	Length (cm)		Fresh wt.(gm)		Dry wt.(gm)		Nod-ules	Galls	Nematode population			
	Shoot	Root	Shoot	Root	Shoot	Root			Females	Eggs	Larvae	Total
F. solani												
MI	40.83	18.93	23.61	16.30	4.28	1.46	25	220	390	29110	4980	34480
MP S/10	40.86	19.42	23.76	15.94	4.35	1.49	27	-	-	-	-	-
MI+MP	34.70	16.20	18.41	12.76	3.26	1.13	20	158	322	17065	3850	21237
MI	42.27	20.43	24.60	16.41	4.60	1.53	29	169	275	20040	3815	24130
MP S	42.17	20.40	24.71	16.31	4.63	1.56	30	-	-	-	-	-
MI+MP	37.10	18.17	21.29	13.15	3.92	1.35	24	119	240	12015	2145	14450
P=.05	2.20	1.74	2.30	1.91	0.39	0.15	9.31					647.52
P=.01	3.02	2.38	3.15	2.61	0.53	0.21	12.76					921.01
P. lilacinus												
MI	42.10	20.62	24.21	16.90	4.69	1.62	28	151	291	23140	4120	27551
MP S/10	40.80	19.84	23.96	16.35	4.44	1.53	29	-	-	-	-	-
MI+MP	36.02	17.82	19.86	12.82	3.54	1.29	20	114	182	10920	2910	13830
MI	44.35	22.24	26.75	18.16	5.04	1.78	33	121	211	14680	2836	17727
MP S	41.76	20.46	24.95	17.40	4.90	1.61	31	-	-	-	-	-
MI+MP	40.25	20.22	23.40	14.70	4.37	1.55	24	64	156	7855	1694	9705
P=.05	2.44	1.93	2.15	1.33	0.51	0.20	6.32					617.13
P=.01	3.35	2.64	2.95	1.82	0.70	0.27	8.66					877.77
P=.05	1.97	1.48	2.04	1.95	0.44	0.18	7.39					567.28
P=.01	2.62	1.96	2.71	2.59	0.59	0.25	9.82					756.56

MI = Meloidogyne incognita; MP = Macrophomina phaseolina.